CIVIL DEFENSE HOME SHELTERS:
A VIABLE DEFENSE STRATEGY
FOR THE 1990S

THESIS

Val James Evans, Major, USAF

AFIT/GLM/LSR/90S-16

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Val James Evans, M.S.

Major, USAF

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Val James Evans

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Abstract

This study investigated the question "Why are fallout shelters not a part of U.S. national defense strategy and policy?" Initial research determined that the U.S. has the technology to design and build shelters, shelters are effective protection from radioactive fallout, and nuclear aggression against the U.S. remains a potential national threat.

The research examined the physical threats posed by nuclear weapons, followed by a brief description of fallout shelters and their ability to shield against fallout radiation in terms of the ratio of time in shelter to amount of exposure. Several opposing arguments from opponents and proponents of a national fallout shelter program were categorized and expressed within U.S. National Security Strategy, military, economic, and political terms.

The principal argument against a national fallout shelter program, including home fallout shelters, is the momentum of over 30 years of successful deterrence. On the other hand, the relatively simple technology, the affordability, and the potential for saving millions of lives in low-risk areas that would otherwise be lost should deterrence fail, argue strongly in favor of a national home fallout shelter system.

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I. Introduction

General Issue

In war, civilian casualties are often equal to or greater than casualties to combatant forces. Civilians killed are called "collateral damage" implying that these losses are less severe than the military losses, but war records show they are not. For example, the total number of civilians killed in World War II (WWII) was 33,065,356, compared to 21,207,516 military killed, a difference of 11,857,840 (36:33). Projected civilian losses in a nuclear war would be much higher. One Federal Emergency Management Agency (FEMA) study, the Nuclear Attack Planning Base - 1990, estimates that in a nuclear attack on the U.S., one in three civilians will be killed by thermal or blast effects, one in 25 will be killed by fallout radiation, and one in six will be injured or ill but not fatally, while one in two will not be injured (25:1). These figures assume some warning, but mainly a duck-and-cover level of defense. The number of deaths and injuries can be reduced with civil defense shelters.

Civil defense (CD) shelters were used in WWII Germany to protect both the military and civilian populations.

Generally known as bomb shelters or bunkers, they were effective in saving thousands of lives in cities like Dresden and Hamburg where extensive Allied aerial bombing caused mass destruction (12:58). These shelters were built above and below the ground as massive reinforced concrete structures designed to withstand direct hits by up to 2000-pound conventional bombs (5:5). They were effective but expensive, and therefore the German government restricted them to only 15 percent of the 70 most strategic cities. The remaining population used reinforced basements and underground tunnel shelters, which were also effective (5:5). With very few modifications, these conventional bomb shelters also provide adequate protection against nuclear weapons (5:5).

Advances in nuclear weapons technology revived public interest in shelters in the 1950s and 1960s in the U.S. and the U.S.S.R., as populations of both countries were threatened with the possibility of mass destruction (14:1; 26:1-4). U.S. public shelter interest and actions peaked during the Kennedy administration. President Kennedy ordered a survey of possible shelter spaces in public and private buildings. By November 1963, this survey had identified 110 million shelter spaces. Of these, 70 million were immediately usable and were approved by building owners. Fourteen million had also been stocked (14:11).

Since President Truman, however, an interesting phenomenon has occurred with U.S. CD efforts. Although no U.S.

President has given CD more than moderate support, and only a fraction of the funds authorized for CD were ever actually appropriated, most CD funds went for research and development and administration, with next to nothing for implementation (14:2-20). Nevertheless, extensive research was conducted on shelter design and the effects of nuclear weapons. One search of the Defense Technical Information Center under the title of "Shelter" produced a listing of approximately 3000 entries pertaining to the sheltering of civilians during nuclear attack (5:3).

Are CD shelters, and specifically fallout shelters, a useful defense against nuclear weapons? Several sources argue that they are. In 1957, the Security Resources Panel of the Science Advisory Committee concluded that military defenses should be accorded the highest priority, but also noted, "these efforts will be insufficient unless they are coupled with measures to reduce the ext eme vulnerability of our people and our cities" (14:6). The committee therefore recommended "a nationwide fallout shelter program to protect the civil population" (39:6). The panel went on to say that they had been unable to identify any other type of defense likely to save more lives for the same money in the event of a nuclear war (39:6-7).

In his 1964 testimony before the Armed Services Committee and the Defense Appropriations Subcommittees of Congress, Secretary of Defense McNamara said he considered

CD "an integral and essential part of our overall defense posture" (14:12). In reference to the nation's offensive and defensive forces, he said, "... a well planned and executed nationwide civil defense program centered around fallout shelters could contribute much more, dollar for dollar, to the saving of lives in the event of a nuclear attack upon the United States than any further increases in either of those two programs" (27:7085).

Additionally, a 1971 General Accounting Office study of CD activities and status recommended, "more attention be paid to improving the fallout shelter system in the U.S." (40:10). The report concluded that:

> ... even though huge increases in nuclear weapon strength and numbers had occurred in the previous ten years, this has not made survival hopeless. With fallout shelters available, millions of lives which would otherwise be lost could be saved in the face of an all-out nuclear attack. (40:10)

Nearly 20 years has passed since this last statement, but no technology, system, or program has been announced or proposed as a better or more cost-effective way of saving civilian lives than with fallout shelters.

Research Problem

Shelter against the effects of nuclear weapons is a mature technology. There has been sufficient research to provide a wide variety of shelter designs from a variety of materials at a variety of costs, with each expected to function reliably with high confidence (5:7).

We have the technology to build fallout shelters which will save millions of civilian lives in a nuclear attack. There is also a preponderance of data to prove that well-designed fallout shelters will protect their occupants against the dangerous levels of gamma radiation found in nuclear fallout.

Given this level of knowledge, why hasn't the U.S. government implemented a national fallout shelter program with shelters and trained personnel to man them? Two possible answers surface. First, no matter how cleverly the shelters are designed to minimize costs, the cost per shelter space must be multiplied by approximately 250 million to accommodate the U.S. population. A more descriptive breakdown would include 160 million shelter spaces with blast protection for the higher risk areas. High-risk areas are those where the direct effects of a nuclear explosion would be felt, i.e., blast overpressure, shock, high winds, and thermal impulse. An additional 90 million shelter spaces are needed with fallout protection for the lower risk areas (5:7). These numbers are a gross generalization, and are only used to emphasize the magnitude of a national shelter construction program.

The other possible answer involves how the public perceives the need for fallout shelters. We have the technology, as previously stated, but U.S. government leaders have not yet solved the political problem of generating the public support and allocating the funds to get

them built. In the past three decades, the CD fallout shelter program has not received the support or the funding needed for implementation (14:2-20). Historically, strong opponents like President Truman; John Foster Dulles, advisor to President Eisenhower; Congressman Albert Thomas, Chairman of the House Appropriations Subcommittee; Senator Henry Jackson; and Secretary of Defense Laird, all helped suppress efforts to build shelters (14:3-16).

Research Question

Given the U.S. has the technology to build fallout shelters that will protect the civilian population from death or injury resulting from nuclear fallout; and, given there is sufficient proof that these fallout shelters are effective against radioactive fallout, why hasn't the federal government implemented a national fallout shelter program designed to protect U.S. civilians from nuclear attack, should our deterrent efforts ever fail?

Justification

There are many valid reasons to support a fallout shelter program in the U.S.:

1) Nuclear weapons will not go away. The U.S. and the U.S.S.R. have been developing variations of a strategy known as counterforce strike (or attack) for over 20 years. Counterforce strike means that military and industrial base targets replace cities as targets. Yet it is this very reliance on counterforce strategies that blocks stabilizing

nuclear-force reductions beyond those currently being considered in the START negotiations (8:42).

Nuclear weapons technology cannot be erased. The U.S. will continue to need nuclear weapons as a retaliatory safeguard against coercion from adversaries who have nuclear weapons now, such as the U.S.S.R. or worse, from those who may suddenly gain the technology, such as a terrorist group or a third world country.

As long as we have them, other countries will continue to develop a nuclear weapons capability. For example, China, Great Britain, France, and India currently have nuclear weapons, and other nations like Israel and Pakistan will soon have them, if they do not have them now. Fallout shelters provide a margin of safety against these forces should deterrence fail.

2) The federal government has invested millions of dollars developing shelter technology, as part of the $2.6 billion spent on civil defense from 1950 to 1985 (2:75). This information is available for anyone to use. The question is not whether fallout shelters are effective protection against nuclear attack, but whether we as a country perceive a threat which justifies the need for shelter, and whether we willing to pay for the cost of shelter implementation (34:190).

3) There is current public interest in fallout shelters. FEMA and Oak Ridge National Laboratory continue to

receive citizen requests for information on sheltering (5:2).

4) The political climate in the U.S. and the world can change quickly. Dozens of scenarios can occur leading to increased threat and increased federal interest in fallout shelter. The 1962 Cuban Missile Crisis was an eye-opener in many respects. All over the country, people were asking their civil defense directors (if they had a civil defense director) what they could do, where they could go, and why more wasn't being done (14:10). Prior to this crisis, with the exception of the Berlin Airlift, the public had shown little interest in shelters, with strong opposition present in Congress (14:10). The time to implement fallout shelters is before a crisis occurs.

Scope

This study defines home fallout shelters and how they protect against the dangerous gamma radiation present in nuclear fallout. This will only be a basic description since an effective shelter need be no more complex than placing mass, space, or both between the shelter occupants and the radiation source - radioactive fallout.

I will limit my analysis to basic designs and emphasize the unprepared basement-type home shelter or its equivalent. I choose this type of shelter because it is readily available to most U.S. civilians, it is affordable, and it provides adequate protection for most fallout

regions. This analysis will center around the work of Robert Ehrlich and James Ring and the mathematical model they developed to calculate the feasibility of this type of shelter as a protection from radioactive fallout.

There are many opponents to the concept of fallout shelters, with military, economic, and political arguments against a national shelter program. I will list several of these arguments from the sources I researched, and then analyze each category of argument.

My analysis includes data from 1943 through 1990.

Method

The method used in this thesis is the logical argument. Thus, the material is presented in a deductive line of reasoning. Following the establishment of a justified reason for examining fallout shelters as a viable subset of U.S. defense policy, I examined the contrary position. There has always been strong opposition to a national fallout shelter program in the U.S. I will articulate the arguments of experts who have opposed fallout shelter and give their reasons in an orderly pattern so that the arguments in favor of fallout shelters would have some substance and meaning.

There is extensive literature available on the technical aspects of nuclear weapons effects and shelter technology that it was tempting to include this material in the analysis. However, this is not the focus of my

research, so I will only present the data that will clarify a particular position, point or argument. Further explanation of terms is provided in Appendix B, the glossary of terms.

The research included a topical search through the Defense Technical Information Center which produced a major study of shelters accomplished by Chester and Zimmerman for FEMA by the Oak Ridge National Laboratory. The bulk of the remaining sources were from current periodical literature mainly from the last decade - I wanted to concentrate on the most recent thinking on the topic - and from FEMA publications. The analysis is my own, based upon the materials I read and my experience as an ICBM Missile Launch Officer.

The substance of the research is to emphasize that the U.S. government has had the technology to build effective fallout shelter for the civilian population for over three decades. There is more than adequate proof that this technology is sound and will save millions of lives if we ever have to use nuclear weapons. The research question is: what forces have been at work in the U.S. military, economic, and political disciplines to block implementation of a national fallout shelter program?

II. Background - The Physical Effects of Nuclear Weapons and the Concept of Fallout Shelters

Overview

The need for CD fallout shelters has been debated in the U.S. for several decades although little has been done to resolve the issue. One common factor that continues to surface is the low level of public understanding and support for CD programs. In his monograph titled: "American Civil Defense 1945 - 1984: The Evolution of Programs and Policies," Dr. B. Wayne Blanchard, FEMA Planning Specialist for Civil Defense Programs, discussed the ongoing debate over the role of CD in U.S. national defense policy. He said:

> Running through this debate [civil defense], on virtually all sides of all the issues, is a phenomenon that in at least one respect parallels the earlier 1960's debates on civil defense -- massive ignorance of civil defense capabilities, purposes, programs, policies, proposals, and possibilities. (14:1)

It is difficult to generate support for a civil defense shelter program if the public has little or no knowledge of what the program is. It is even worse, if they have false or misleading information.

This chapter presents background information on CD shelters in general, and specifically on three key considerations - the physical effects of nuclear weapons detonations (NUDETs) and the dangers and challenges they provide for the civilian population and shelter designers;

the general types of fallout shelters and the elements of a shelter, such as size, composition, and protection factors, which help shield against radioactive fallout; and a shelter model which stresses the importance of shelter time over shelter design as a more favorable defense against fallout.

The physical properties of a NUDET determine the type of shelter to design and the structural characteristics needed. Some of the more destructive properties or elements of an explosion, such as blast, winds, shock, fires, and electromagnetic pulse (EMP), require a very rugged and complex shelter. Other NUDET elements, such as initial nuclear radiation and radioactive fallout, are equally dangerous, but not as violently destructive. Thus, radiation can be shielded against in low-risk areas with a fallout shelter, if sufficient mass or distance is provided for the given radiation level. The radioactive components of concern are alpha and beta particles and gamma rays. All three are present in radioactive fallout, which is the element of focus in this study, since the need for fallout shelters is central to the research question. The last area discussed is home fallout shelters and the concept of an unprepared basement-type fallout shelter or its equivalent and the shelter model developed for it.

One of the more positive studies concerning fallout shelters used a mathematical model to estimate the a civilian population's ability to survive the effects of nuclear

fallout (11:267). This model, developed by Robert Ehrlich and James Ring, presupposes an understanding of the effects of nuclear fallout on living things. Since this model is a key premise to the viability of fallout shelters, it is useful to understand the effects of nuclear weapons. The following section provides basic information on the destructive forces produced by a NUDET and dangers present in nuclear fallout. Knowledge of these threats is important to a valid argument in favor of fallout shelters.

Physical Properties of Nuclear Detonations (NUDETs)

To adequately discuss fallout shelters, a review of the most significant physical effects of NUDETs is needed since they all have an impact on shelter design. The most critical effects are blast overpressure, thermal radiation and fires, nuclear radiation, and fallout radiation. Much of the information about these elements came from the work of Chester and Zimmerman (1986) who in turn credit The Effects of Nuclear Weapons (Glasstone and Dolan, 1977). This data is based upon extensive U.S. weapons tests in the 1950s and early 1960s.

The only real information on the direct effects of nuclear weapons on populated cities comes from the atomic bombings of Japan during World War II. These effects, both upon structures and upon people, are described in a study titled "Committee for the Compilation of Materials on

Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki (1981)" (5:13).

The physical effects of a NUDET are similar to other types of explosions, but many times greater and with the addition of nuclear radiation. The principal dangers associated with an explosion are blast overpressure, shock or ground motion, initial nuclear radiation, general nuclear radiation, thermal effects and fires, nuclear fallout, and electromagnetic pulse (EMP) (5:13-28). These characteristics are easier to understand when reviewed one at a time, even though their combined effect provides a more realistic assessment of the massive force involved.

Blast overpressure, thermal radiation and fires, EMP, and initial radiation require much stronger shelter construction than found in a typical fallout shelter. The blast shelter designs will be needed to counter these forces for the percentage of the U.S. population in the higher-risk areas -- those areas co-located with strategic military installations or industries.

Blast. When a nuclear weapon is detonated, a high-pressure wall of air, the blast wave, is driven away from the point of the explosion. The blast wave travels faster than the speed of sound in air. Thus, its effect at some distance from the explosion will not be observed until several seconds after the NUDET has occurred. The pressure of this blast wave, the overpressure, decays as the wave travels away from the explosion. Nevertheless, the blast

wave will flatten structures in its path if they have not been built to withstand such force. This mass destruction of property is the usual effect desired by military planners. It determines the choice of weapon size, burst height, and aiming point (5:13).

The blast wave is also accompanied by a high-velocity wind. For example, a blast wave with a 50-pound-per-square-inch (psi) overpressure (3.3 atmospheres) is accompanied by a 1000-mph wind (1600 km/hr). Even a 5-psi overpressure (0.3 atmospheres) generates a peak wind of 160 mph. This high-velocity wind is responsible for much of the destructive effect of nuclear weapons on above-ground structures such as ordinary frame houses. The high wind can also blow building debris into hardened structures causing more damage than just the wind alone (5:14).

Another interesting phenomenon is reflected overpressure. When the blast wave strikes a flat surface head-on, a reflected overpressure is produced as the result of an almost total stoppage of the airflow. This reflected overpressure can increase to a value of up to eight times greater than the original wave. This effect can be catastrophic; for example, if a 100-psi (6.9 atmospheres) blast wave reflects from a flat surface, it will momentarily produce an overpressure of 500 psi (34 atmospheres) on the surface (5:14).

Finally, there is another force associated with the blast wave known as the negative phase. After the blast

wave passes, there will be a reverse flow of the wind. For a short time the pressure will drop below normal by about three psi (0.2 atmospheres). This negative pressure is usually considered negligible compared to the initial blast overpressure; however, a negative pressure of only three psi can lift a 3-foot-thick slab of concrete if it is not properly anchored. There is another problem with the negative phase force. Its force is in the opposite direction of that which most structures are designed to withstand (5:14). A fallout shelter will not be adequate for these weapon effects. Blast overpressure and overpressure winds require a much stronger blast-type shelter.

Ground Motion and Shock. If a nuclear weapon explodes near the ground, as with a low airburst, the blast overpressure depresses the surface of the ground abruptly. The magnitude and speed of movement will be a function of the degree of overpressure and its duration plus the nature of the soil. If the explosion contacts the surface, as in a ground burst, some of the blast energy is transmitted directly into the ground. This energy produces compression and shear motions which propagate radially outward from the explosion (5:22).

At close ranges the ground-transmitted shock arrives after the blast overpressure or air-induced ground motion. But at greater distances from the NUDET, ground-transmitted shock often arrives first. The exact circumstances depend

upon a complex mixture of seismic velocities of the soil and rock layers at the location surrounding the explosion (5:22).

At very high overpressures, in the hundreds of psi range, ground motions can be several feet. This is not usually a problem for home shelters, since they would not likely be anywhere near ground zero. If a person is standing on a concrete floor, however, his legs could be broken by the sudden ground motion accompanying overpressure greater than 75 psi (5:22). Extensive research by J.R. Rempel, in his 1967 study on this topic, concluded that this problem is minor with blast waves below 50 psi, except for possible injury due to people losing their balance (5:22). A fallout shelter will not be adequate for these weapon effects. Shock and extreme ground motion will require a much stronger blast-type shelter.

Thermal Radiation and Fires. A nuclear weapon exploded in the lower atmosphere will produce approximately 35 percent of its energy as thermal radiation. This intense energy can ignite combustible materials for a radius of up to 20 miles from a high-yield explosion, though 2 to 8 miles is a more commonly expected radius (5:22). This is not usually a major concern for underground shelters, unless they are in the basement of a building. The basement shelter will probably not burn, but the heat, smoke, and toxic gases of the aboveground burning may endanger shelter occupants.

Another complication caused by the thermal energy may arise. At locations exposed to high thermal effect, metal blast doors and ventilation intakes/outlets at the surface may be sufficiently heated by the thermal radiation before the arrival of the blast wave, to lose their intended strength levels, resulting in failure (5:23).

Nuclear weapons can also be considered incendiary weapons over much of the area they affect. This is true partly because of the thermal radiation which can ignite dry materials at overpressure as low as 2 to 3 psi, resulting in fires for a radius of up to 4 to 5 miles with a one MT surface burst, and up to 6 to 8 miles with a one MT airburst. The blast wave can also cause fires by overturning furnaces, stoves, and heaters, by breaking gas lines, and by shorting electrical circuits (5:23).

Fires, based on the experiences at Hiroshima and Nagasaki, take on some very interesting characteristics of their own. Also known as conflagration or superfires, their intense heat, self-generated gale-force winds, and asphyxiating gases, lead some modelers to predict that the fires which follow the blast will produce more casualties than the overpressure models alone predict (8:12).

FEMA and its predecessors have sponsored much fire research. Most of this research is only slightly related to shelters other than designated fallout shelters. Since these fallout shelters are not designed to protect against fires, FEMA concluded the vast majority of occupants would

not survive if fires swept the area. However, more than enough information is available to design and build shelters that would protect their occupants against conflagration burning over them (5:25). Fallout shelters might be adequate shelter against thermal radiation and fire. It depends on the type of shelter, placement, and location in reference to the NUDET.

Electromagnetic Pulse (EMP). One aspect of a high-altitude-burst NUDET that has received increased attention is electromagnetic pulse. Simply put, EMP is that portion of the electromagnetic spectrum in the medium to low frequency range, extending from the frequencies used in radar and TV down to those used in electric power. Since most of the EMP energy is radiated in the frequencies used for radio and TV, it is also called radio flash and is quite different from thermal or gamma pulse radiation (9:49).

EMP is dangerous because it can be collected and concentrated, much like the sun's rays can be focused with a lens to produce a fire. Some common EMP energy collectors are communications station antennas, power or telephone lines, railroad rails, shallow buried pipes or cables, and steel-bodied cars. Sufficient energy can be collected by these objects to cause damage to connected electric or electronic equipment (9:49). (See Figure 1)

EMP can cause two kinds of damage. First, functional damage that requires the replacement of a component or

piece of equipment. Second is the operational upset of equipment such as opening of circuit breakers or worse, erasure of a portion or all of a computer memory. However, the vulnerability of individual electric or electronic equipment can vary greatly. Transistors and microwave diodes are more vulnerable than vacuum tubes or electric motors (9:52). A fallout shelter will be inadequate protection against EMP, which requires a more complex shelter structure.

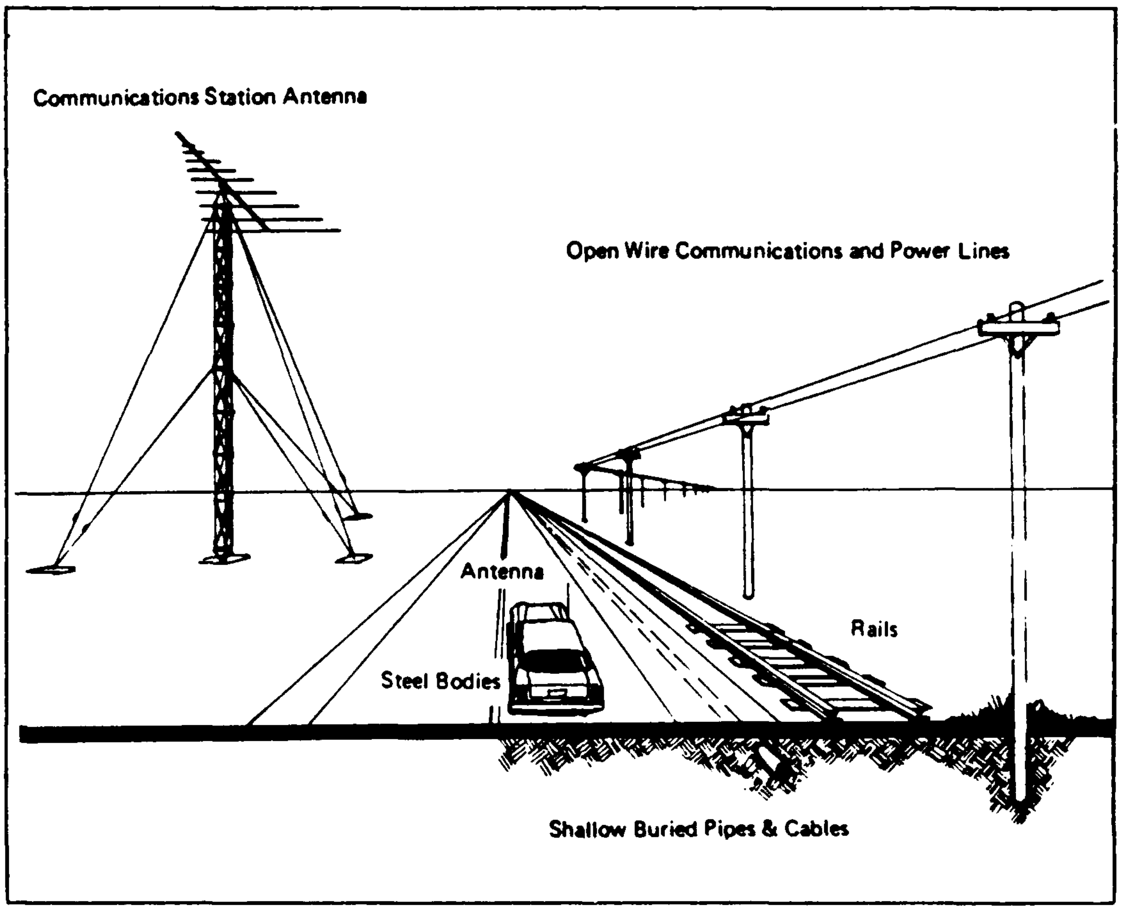


Figure 1. Electromagnetic Pulse (EMP) Energy Collectors (9:48)

Initial Nuclear Radiation. Initial nuclear radiation is that neutron and gamma radiation which is emitted by a nuclear weapon within one minute of its detonation. The source of the neutron radiation is principally the fission or fusion reactions occurring in the weapon, including delayed neutrons emitted by some fission products. The source of gamma radiation is the fission reaction, decay of fission products, inelastic collision of neutrons, and neutron capture reactions, particularly those with nitrogen in the atmosphere and within the shelter structure (5:19). For a more detailed description of these terms, refer to Appendix B.

Initial nuclear radiation is attenuated by the atmosphere and is of little consequence from high-yield weapons of low overpressure. It is more important as a shelter design consideration at overpressures above 30 psi and for weapon yields in the kiloton range of tens to a few hundred (5:19).

The production of initial nuclear radiation has been studied extensively and is well understood, as is its interaction with matter and the shielding capabilities of different materials in a variety of configurations. The actual radiation present in a nuclear attack depends on the weapon yield and the weapon design, and can vary by as much as a factor of 5 for each given yield (5:19). To protect against initial nuclear radiation, thick barriers of

concrete, earth, or other materials with high mass are required. Most fallout shelters would not be adequate protection.

Radiation. For most of the U.S. population, nuclear radiation, the noiseless, odorless, unseen, unfelt something that can be so deadly, seems, as Winston Churchill said of Russia, "a riddle wrapped in mystery inside an enigma" (9:5). It need not be that way since a few hours of study on the basic physics of nuclear radiation would be adequate to make it understandable to almost anyone. An understanding of nuclear radiation also makes the successful design and use of home fallout shelters much easier to conceive and accept.

Since all three types of radiation are found in radioactive fallout, a fallout shelter must provide some level of protection against each. Due to their physical properties, alpha and beta radiation are relatively easy to protect against. Gamma rays, on the other hand, present a much greater threat, needing careful shelter design and construction to reduce exposure. Each type of radiation is described in enough detail to make these points clear.

The three common types of nuclear radiation are alpha particles, beta particles, and gamma rays. It is important to understand the properties of each and the dangers associated with them. A summary is found in Table 1, and definitions of the terms used are found in Appendix B.

Table 1

Characteristics of Nuclear Radiation (9:18)

Radiation Type	Kind	Atomic Mass Units	Electrical Charge	Remarks
Alpha	Particle	4.00277	+ 2	Identical to a helium atom, less its electrons
Beta	Particle	0.000549	- 1	Identical to a high-speed electron
Gamma	Energy	None	None	Electromagnetic wave of energy

Alpha Radiation. Alpha particles emitted by radioactive materials are often called alpha radiation or simply alpha. They are comparatively large, heavy particles of matter which have been ejected from the nucleus of radioactive material with very high velocity. An alpha particle has a net positive electrical charge of two and an atomic weight of 4.00277. Thus, the alpha particle is equal to a helium atom with two protons and two neutrons (9:17). When compared to beta and gamma radiation, alpha is relatively slow, as might be expected due to its size and weight. Alpha radiation is literally tiny pieces of matter traveling through space at speeds of 2,000 to 20,000 miles per second (9:18). When a radioactive atom decays by emitting an alpha particle, transmutation of this atom

to an atom of lower atomic number and lower atomic mass occurs.

Alpha particles lose their energy rapidly and hence have a limited range of only six or seven centimeters in air. They can be completely stopped by a sheet of paper. When the alpha particle is stopped, stabilized, or reaches ground state, it has picked up two electrons, available in space, and thus becomes a neutral helium atom (9:21). Fallout shelters can easily protect against alpha radiation. It would pose a problem only if brought into the shelter on contaminated clothing, for example, or if accidentally inhaled or ingested.

Beta Radiation. Beta particles are identical to high-speed electrons. They carry a negative electrical charge of one and are extremely light, traveling at speeds nearly equal to the speed of light, 186,000 miles per second. Although the atomic nucleus does not contain free electrons, only protons and neutrons, the electrons which are emitted as beta particles result from the spontaneous conversion of a neutron into a proton and an electron. The neutron which lost or emitted the beta particle has become a proton with a positive charge and thus the atom has been changed. Transmutation has produced an atom with a higher atomic number.

Beta particles do not lose their energy as quickly as alpha particles because they are smaller, lighter, and move

at much higher speeds. Unlike alpha particles which tend to move in straight lines, a lightweight beta particle can easily bounce around in any material. Materials with low atomic numbers, like aluminum, glass, or plastics normally make good beta shields (9:22).

Fallout shelters also easily protect against beta radiation. It would pose a problem only if brought into the shelter on contaminated clothing, or if accidentally inhaled or ingested.

Gamma Radiation. Gamma rays are electromagnetic radiation which travel at the speed of light. They have no mass or electrical charge. Gamma rays are similar to X-rays, but there are two important differences. Gamma rays are generally higher frequency than X-rays, and originate in the atom's nucleus, while X-rays originate in the cloud of electrons which surround the nucleus (9:18). The emission of an alpha or beta particle from the nucleus of an atom leaves the nucleus with excess energy known as an excited state. This process is accompanied by the emission of gamma rays as the atom attempts to reach ground, or a more stable condition. Since gamma rays are not particles, they have no mass and can travel at the speed of light. Thus, they do not lose their energy as rapidly as alpha or beta particles (9:22).

Gamma rays are highly penetrating, with their effective range depending on their energy. The effect of air on gamma rays is so small, that it is not practical to measure

its range in terms of inches, feet, or meters. Their penetrating power is measured in terms of the amount of material needed to reduce gamma radiation to some fraction of its original value (9:23).

Radioactive decay in general often results in transmutations where one element is changed into another. Some radioisotopes decay directly into a stable state in one transmutation. Others decay through a series of steps or transmutations forming several different radioactive elements, called daughter products, before finally reaching a stable state (9:19).

Gamma radiation poses the greatest challenge to fallout shelter design. To protect against it, the shelter must have mass, space, or both. This is discussed in greater detail in the shelter section, but a fallout shelter can provide adequate protection from gamma radiation in fallout.

<u>Fallout.</u> When a nuclear weapon explodes so that the fireball touches the ground, particles of soil and debris are drawn up into the fireball and subsequent cloud. Here fission products from the weapon are deposited in and upon the particles. These contaminated particles, known as fallout, settle by gravity out of the atmosphere at a rate depending on their size and weight, the height to which they were raised, and the wind speed. The majority of the fallout settles out in 24 hours, but the very fine particles falling from extreme altitudes can take weeks, months

or even years to settle out. This late-arriving fallout represents a very minor hazard to human health, because the radiation dose rate from fallout decays quickly. Compared to the reference dose rate of one hour after a nuclear attack, the dose rate decays to one percent in about two days, to 0.1 percent in about two weeks, and to 0.01 percent (1/10,000th of the original) in about three months (5:26). The danger is primarily from the fallout arriving within the first day or two after the explosion.

The prediction of exact fallout patterns prior to an attack is impossible, since the amount and location of fallout depends on the number of ground-burst weapons used, and the wind speed and its direction at the time of the attack. FEMA has devoted considerable attention and resources to collect sufficient information for any practical civil defense program. They determined a fallout shelter is needed everywhere outside the areas exposed to the risk of blast (See Figure 2). Moderate radiation protection would save nearly everyone and would significantly reduce the amount of injury from fallout radiation (11:279). Additionally, survivors who have been adequately sheltered from fallout will actually increase their tolerance of subsequent radiation exposure which may occur during cleanup efforts (5:28).

Protection against fallout is much easier than protecting against the other effects of NUDETs. Thus, fallout shelters are less complex and less expensive than blast

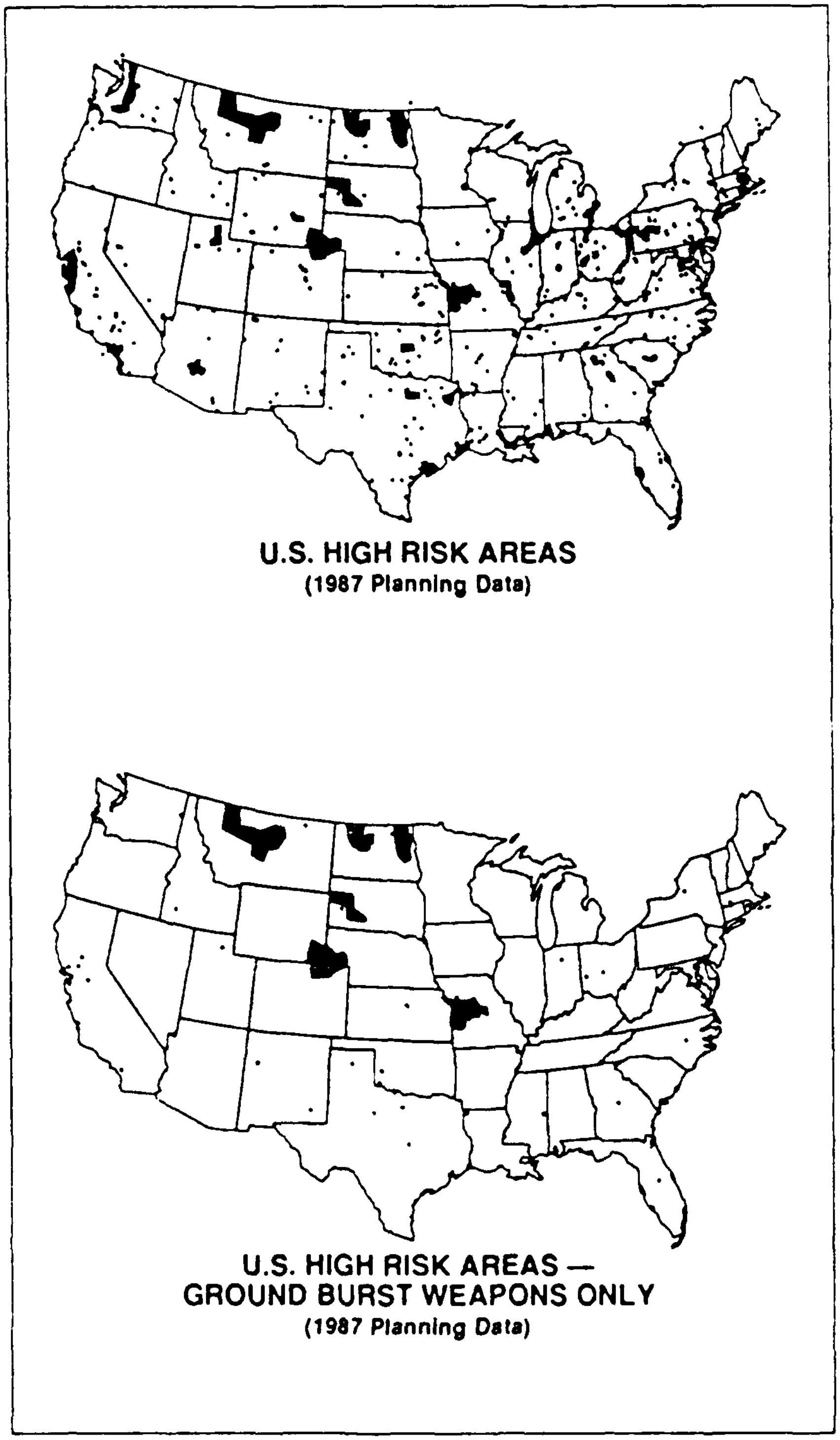


Figure 2. U.S. High-Risk Areas (16:17)

shelters and are considered sufficient shelter for the lower-risk areas of the U.S. by most experts.

Types of Shelters

One effective approach to shelter design is to study each component of the shelter in terms of the weapon effect that it protects against. I use the same logic in describing the types of shelters. There are also some interesting synergisms with shelters which make the shelter types less distinctive as one form or another. For example, efforts to improve a shelters radiation protection also improve its blast resistance (5:33).

Shelters to protect civilians against blast and fragments were very effectively designed and developed during World War II. They were generally known as bomb shelters and included elements such as: blast doors, protection against chemical agents, and use of subsurface construction. Since Germany was subjected to extremely heavy aerial bombing, they developed some very effective technology against aerial weapons, called bunkers (5:5). These massive concrete protective structures were designed for civilian shelters and for submarine pens.

German Sonnenbunkers were also developed. These were above-ground reinforced concrete buildings designed to resist direct hits from aerial bombs, starting at 500 pounds. Eventually, the Sonnenbunkers were resistant to bombs over 2000 pounds. But, both of these bunker-type

shelters were expensive, and were therefore restricted by the German government to only 15 percent of the 70 most strategic cities by 1944. The rest of the population had reinforced basements or underground tunnel shelters which were also effective (5:5).

Relatively few improvements were needed to make the WWII vintage bomb shelters effective against nuclear weapons. Their massive concrete and underground construction provided inherent protection against nuclear radiation. To convert these bomb shelters into high-performance nuclear weapons shelters required the addition of radiation protection at the entrances - either through more massive blast doors or entryways with one or more turns, and shock isolation (5:5). Filters were also added to keep out radioactive fallout and dust.

Blast and Fire Protection. Blast overpressure is the major effect considered in a blast shelter. Blast energy is overcome by building a structure that either resists or yields to the force. For resistance, a strong structure capable of withstanding the direct blast is built. Reinforced concrete is generally used for this type of shelter. For example, a hardened basement or a shallow-buried reinforced concrete structure. For the yield strategy, a structure that is weak and which yields to the blast overpressure is built. An example of the yield-type shelter is a corrugated metal culvert, buried deep enough in granular well-drained soil to attenuate the blast load (5:34).

Blast shelters are most economically produced when they are incorporated into new building construction - usually in the basement. Such structures can be built of concrete in rectangles, pipes, domes, or arches (5:34).

A fire shelter must protect against heat, carbon monoxide and other poisonous gases, and burning debris. Most shelters designed to withstand blast or radiation will also protect against fire if they are designed to provide an adequate supply of fresh air. This may entail ventilation systems that draw air from openings far away from the shelter or other buildings (5:23).

Initial Nuclear Radiation. For protection against initial nuclear radiation at overpressure greater than one atmosphere from medium-yield weapons, a 3-foot-thick barrier of concrete or a layer of at least four feet of soil is needed. Shelters designed for two to three atmospheres of overpressure from medium-yield weapons require a 5 to 6-foot layer of soil to shield against initial radiation (5:34,38).

Fallout Shelters. Achieving adequate protection from radiation is the major objective of fallout shelters. More specifically, the real concern of fallout shelters is to protect against gamma radiation, since the low-penetrating alpha particles and beta radiation do not present a serious threat. There is a wide variety of effective designs for fallout shelters, each providing a degree of protection for

its occupants. These can all be grouped into one of two basic shelter strategies: barrier shielding and geometry shielding (see Figure 3).

Fallout Barrier Shielding. In the simplest terms, the principle of radiation protection is to place either mass or distance, or both if possible, between the people being protected and the radiation source. The mass can be any material: earth, concrete, steel, water, or even air, although, some materials obviously serve as better radiation shields than others. A concise and detailed description of the interaction of radiation with shielding material is given in Glasstone and Dolan (1977) (5:39).

To provide barrier shielding from fallout radiation, the radiation intensity must be decreased. How effective the shielding material is at decreasing the radiation intensity depends on the mass of the material per unit of area between the radiation source and the point where it is measured. The whole purpose of the shielding material is to attenuate the gamma rays. The material's effectiveness in doing that is measured in two ways. The first measure involves the concept of "tenth-value thickness," while the second measure involves the "protection factor" concept (5:41). A tenth-value thickness is defined as:

> The thickness of any given material that will only transmit a radiation dose one-tenth of that which falls upon it. In other words, one tenth-value thickness of any material would reduce the gamma ration by a factor of ten. Each succeeding tenth-value thickness would bring about a further reduction by another

factor of ten. For fallout gamma radiation, the tenth-value thickness is approximately eight inches of concrete or 12 inches of soil. These thicknesses can also be translated into the barrier's mass per square foot of exposed area. Thus, any shield weighing about 100 pounds per square foot would equal one tenth-value thickness. A shield weighing 200 pounds per square foot, two tenth-value thicknesses, will reduce the radiation by a factor of 100, and a 300 pounds per square foot shield, three tenth-value thicknesses, will reduce the radiation by a factor of 1000. (5:41)

A protection factor (PF) or fallout protection factor is the factor by which radiation intensity is decreased as it passes through a shield. One tenth-value thickness provides a PF equal to ten. This protection factor concept can be applied to entire shelter structures, as well as individual barriers or shields. For fallout shelter design, the minimum recommended PF is 40 or about 1.6 times the tenth-value thickness. Either of these two methods of measuring the effectiveness of fallout radiation shielding can also be used to describe the level of protection provided from fallout radiation (5:42).

Geometry Shielding. The radiation protection provided by a fallout shelter is difficult to calculate accurately. This is due to the complex set of variables involved in the calculations, such as the type of radiation and its interaction with different types of shielding material. The protection calculation also involves the variability of the barrier shielding around a shelter, because the shielding is seldom a uniform thickness.

Geometry shielding is a technique used to analyze the protection level. The technique involves dividing the

shield into fairly uniform sections and calculating what fraction of the radiation gets through each element of the shield. The penetration of each element is by engineering estimation for mass thickness or by computer or hand calculation. The data is then reduced to relatively simple graphical calculations which are summed to reveal the amount of radiation entering the shelter (5:43).

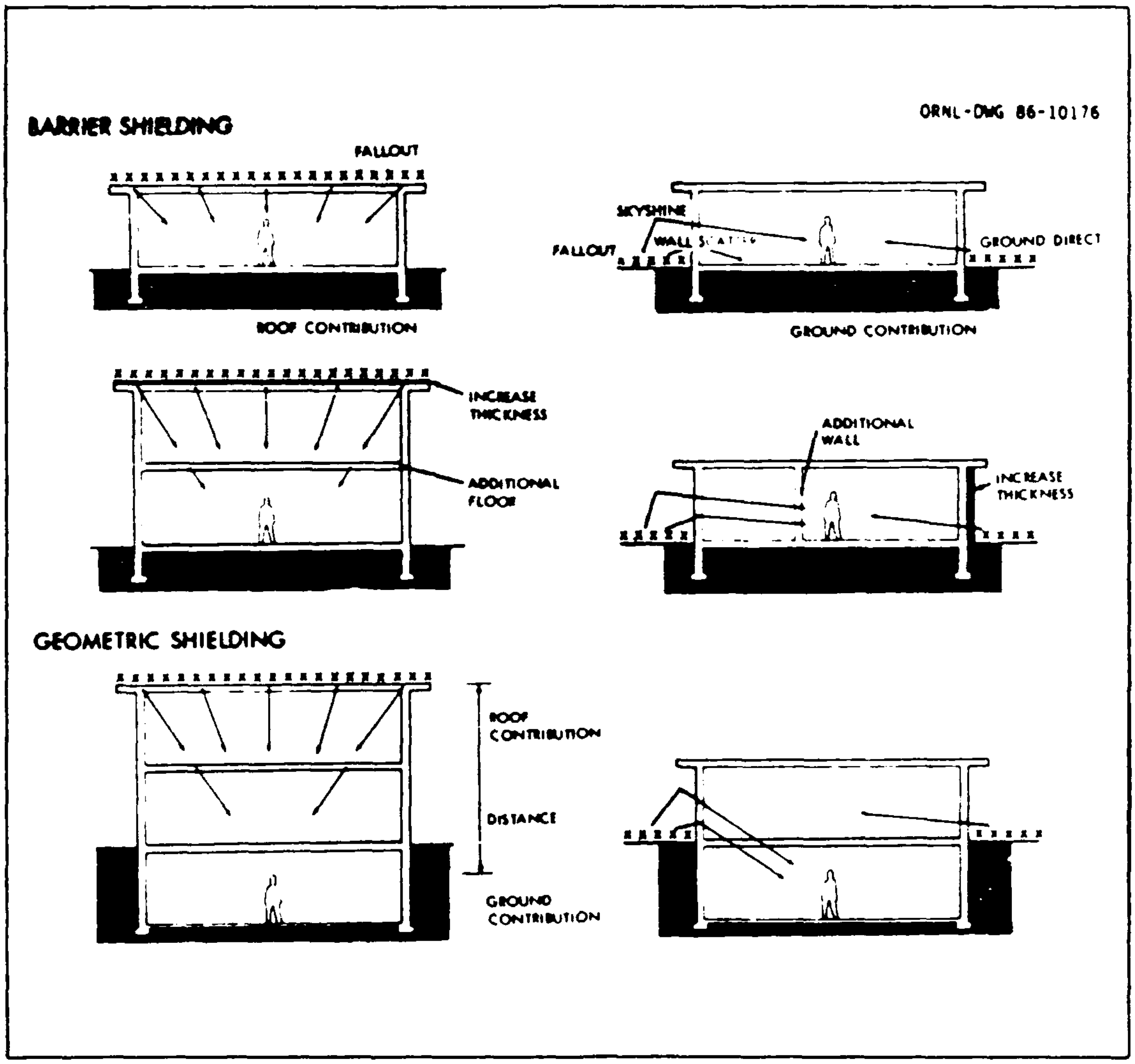


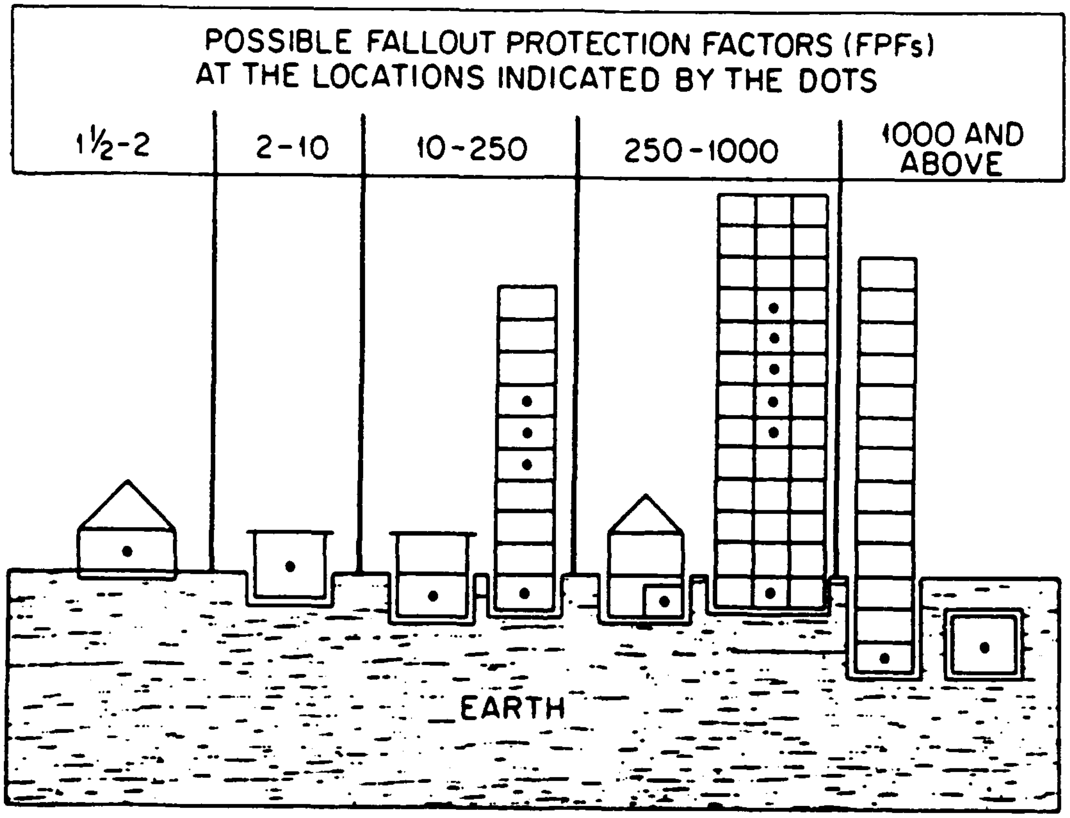
Figure 3. Barrier Shielding and Geometry Shielding (5:49)

Home Fallout Shelters

A shelter should provide a place of safety from natural or man-made hazards such as a tornado or nuclear fallout radiation (23:2). Thus, a properly designed fallout shelter safeguards against fallout, but it can also protect against tornadoes or other similar hazards. In general, a home fallout shelter should be designed to provide a PF of at least 40. This will reduce the radiation exposure rate to only 2.5 percent the exposure rate in an unprotected location (23:2) (see Figure 4). Such a shelter will also provide some limited protection against blast and fires, but fallout radiation shielding is the primary objective of a home fallout shelter design and the emphasis of this section. It would not be adequate for a high-risk area where the more severe nuclear weapons effects are felt. One other point of clarification; the terms home fallout shelter, fallout shelter, home shelter and shelter will all be used to mean the same thing in this section - a home fallout shelter.

Home fallout shelters can take a variety of forms. They can be designed into new construction or added to an existing home - in either the basement or another protected part of the house or property. They can be dual-use or reserved for emergencies only, and vary in size and capacity. There are dozens of designs available, with a representative sample in Appendix A. For ease of description, these shelter designs are grouped into two

categories: stand-alone shelters, and modified basement shelters. Each type is described in its generic form.



NOTE: Deep basements and buried shelters have high FPFs (1000 and above). They provide good protection against gamma radiation from fallout. Tall buildings also provide good protection against gamma radiation from fallout in the locations indicated by dots in the drawing, but they provide little protection against blast. The FPFs indicated above are for isolated buildings. The FPFs would be higher for ground-level and below-ground shelters that are surrounded or partly surrounded by buildings. The first floors of houses and partially buried basements have low FPFs and provide little protection against gamma radiation from fallout.

Figure 4. Fallout Protection Available in Different Structures (24:4)

Stand-alone. The basic generic stand-alone shelter design is a structure that will accommodate up to six adults, based on the FEMA recommendation of at least ten square feet per person (23:4). It can be underground, which is preferred for maximum protection and minimum cost, or above ground, in those areas where water tables are too high to accommodate subsurface construction, or where personal preference dictates.

Modified Basement. There is a wide variety of basement shelter designs available. Whether designed into the initial construction, which reduces the cost per space, or added later, the objective is to achieve a PF of 40 or better as a shield against fallout radiation. Therefore, since most fallout radiation enters the basement of a one story house from the fallout particles on the roof, and very little enters through the ground, due to the shielding effect of the earth outside the basement walls, the key to a successful home fallout shelter is adequate mass in the shelter ceiling (19:5). There are many plans, but the basic ideas center on the placement of mass or distance or both between the fallout radiation and the occupants. If this can be accomplished, an effective shelter is available.

Unprepared Basement Shelter

In 1987 Robert Ehrlich and James Ring, researchers at George Mason University, Virginia, and Hampton College, New

York, respectively, wrote a paper based on a mathematical model they developed to test the feasibility of sheltering the U.S. population from fallout, following a large-scale nuclear attack. An important question addressed in their work is whether under the conditions of a large-scale nuclear attack, sheltering a relatively unprepared population is feasible (11:278). The U.S. is a population unprepared for nuclear attack. Sensitivity tests of the various parameters of their model showed that relatively low PF areas like basements or inner rooms of normal homes or other buildings, could quite adequately serve as shelters for most areas of the U.S. (11:267). This means with very minor preparation and training, millions of Americans can survive the lethal effects of fallout.

Attack Factors. The Ehrlich and Ring model, referred to hereafter as 'the model' places a strong emphasis on time and radiation levels. These variables are discussed next, but both are also affected by ten other factors under the attacker's control:

a) The total yield, in megatons, of all weapons delivered.

b) Average yield per weapon - other things being equal, many smaller warheads produce higher initial radiation levels on the ground because the radioactive fallout arrives quicker than with larger weapons, when it is more intensely radioactive.

c) Fission-Fusion ratio - which determines the dirtiness of the weapon. A greater fission fraction increases the amount of long-lived radioisotopes, and the hazard.

d) Altitude of detonation - the single most important variable affecting radiation levels. Ground-burst detonations produce far more fallout than do air-bursts.

e) Attack scenario. It is purely speculation what targets an attacker will choose, but the Soviet Union clearly has enough warheads to target every U.S. location of military or economic significance.

f) Nuclear reactor attacks. There are strong arguments for and against attack on nuclear reactors. It would damage our ability to generate electricity, but the increased levels of long-lived radioisotopes in the fallout would pose a serious hazard for the attacker as well.

g) Soil conditions - finer dust particles remain aloft longer and are less intensely radioactive and more widely dispersed.

h) Weather conditions - such as the speed and directions of the wind and the presence or absence or precipitation, which are extremely important to the factors in determining the patterns of fallout on the ground.

i) Terrain - which determines if the fallout is uniformly deposited or forms an uneven layer. The non-uniform layer would result in lower exposure rates.

j) Location - relative to the detonation point, is of the greatest importance in determining how much fallout will be deposited on the ground (11:268).

Time. Time is vitally important to the measurement of radiation levels when considering the feasibility of sheltering. Three time factors are used in the model. First, is t_1, which is the radiation intensity when the bulk of the fallout arrives on the ground. Second, is a time concept called the $t^{-1.2}$ law. Each individual radioisotope in fallout decays exponentially with a specific half-life. Empirically, researchers found that for the first six months, the radiation from all the isotopes

combined is closely approximated by the $t^{-1.2}$ law, i.e., $D = D_1 t^{-1.2}$, where D_1 is the dose rate at time t = 1 hour (11:269). This law holds only after the fallout has been deposited.

The feasibility of sheltering depends critically on the way the cumulative radiation varies over time. So, for any given cumulative dose, the fraction of that dose received after some variable of time (t) depends greatly on arrival time (t_1). A short fallout arrival time means a higher initial radiation intensity level and higher cumulative dose, but it also means that a smaller fraction of the cumulative dose will be received after some time t. This is the basis for the importance of sheltering when fallout arrives quickly (11:269).

The third time criterion is $t^{-2.2}$. It is the same concept with a different exponent which represents a steeper decline in radiation intensity. All these time variables share three limitations:

a) empirical data shows the t-laws are only equal to actual fallout decay measurements for the first six months,

b) the t-laws only pertain to undisturbed fallout,

c) the length of the war.

If NUDETS occur over a long period of time, the actual radiation levels will deviate from the t-laws until a t_1 is established (11:269).

Radiation Protection. The model considers five protection factors associated with the shelter and human physiology:

a) Extent of shielding - the PF of the shelter. An ordinary below-ground home basement typically has a PF of at least 20, although significantly higher PFs could be achieved by piling dirt up around the foundation before a nuclear attack. For each 0.305 meters of dirt an additional PF factor of ten is added, but since the factors are multiplied, one meter of dirt would provide a PF of 1000. In addition, features of the natural terrain can also lead to much higher PFs. For example, the basement of a home on a 16-meter hemispherical hill would have a PF of 67 rather than 20, a gain of a factor of 3.3 due to terrain.

As far as availability of shelters in concerned, about half the homes in the U.S. have basements and most tend to be concentrated in the northern states. Furthermore, many multi-story commercial and apartment buildings have suitably high PF areas (PF of at least 20), even if they do not have a basement (11:269).

b) Shelter time strategy - the length of time spent in the shelter. Of course the initial time in the shelter is critical, but so is the strategy adopted for time in the shelter after emergence. For example, it might be possible to leave the shelter much sooner if a greater fraction of the day is spent in the shelter after emergence. Of course, the strategy used would be affected

by outside constraints, such as insufficient food or water which may force a shelter occupant to leave the shelter before outside levels are tolerable.

c) Shelter contamination - which can occur if fallout is blown into the shelter, or through poor decontamination of shoes and clothing by those who have been outside the shelter. With moderate precautions, the seriousness of this contamination could be controlled.

d) Ingestion hazard - caused by inhaling fallout particles or swallowing contaminated food or water.

e) Biological repair - based on the radiation delivery rate. For a given cumulative radiation dose, the biological harm depends upon the rate at which the dose was delivered. Promptly delivered doses, those where a high dose is received within a short exposure time, are believed to be much more harmful than gradually delivered doses, those where a small dose is received over a long exposure time. The difference is attributed to an effect called biological repair. This effect is important for shelter protection because both the cumulative dose and the time period over which it was received determine the degree of damage to living cells (11:270).

<u>The Model.</u> The model used three components: an attack scenario and resulting cumulative fallout dose, a time dependence of radiation intensity, and a shelter time strategy (11:271). These are described in detail, beginning with the attack scenario.

Attack Scenario. The attack used in the model was a simulated all-out nuclear attack against the U.S. urban-industrial areas and the ICBM missile silos. Ehrlich and Ring (E/R) used data calculated by Oak Ridge National Laboratory, with parameters defined by FEMA.

The statistics included:

1) 6559 megatons delivered,
2) 1444 weapons yielding from 1 to 20 MT each,
3) 50 percent fission and 50 percent fusion,
4) 77 percent ground burst, by megatonnage,
5) no nuclear reactors targeted,
6) all major urban-industrial areas targeted, and
7) a uniform west wind of 40 KM/hour (11:272).

Using specific yield weapons on specific yield targets, a fallout map may be generated (see Figure 5), and superimposed over a map which accurately shows the U.S. population concentrations. The unit/time dose rates, and the percentages of U.S. land and population affected are given in Table 2.

Table 2 gives a picture of the fallout problem that would face various percentages of the country. It is worth noting that the situation facing survivors is quite different when viewed as a percentage of land rather than as a percentage of population. The percentage by population is probably overly pessimistic since it assumes prewar populations with no evacuation, and unrealistically treats the survivors of direct NUDET effects in the high fallout regions the same as survivors in the low fallout regions where no direct effects are found. Thus when examining

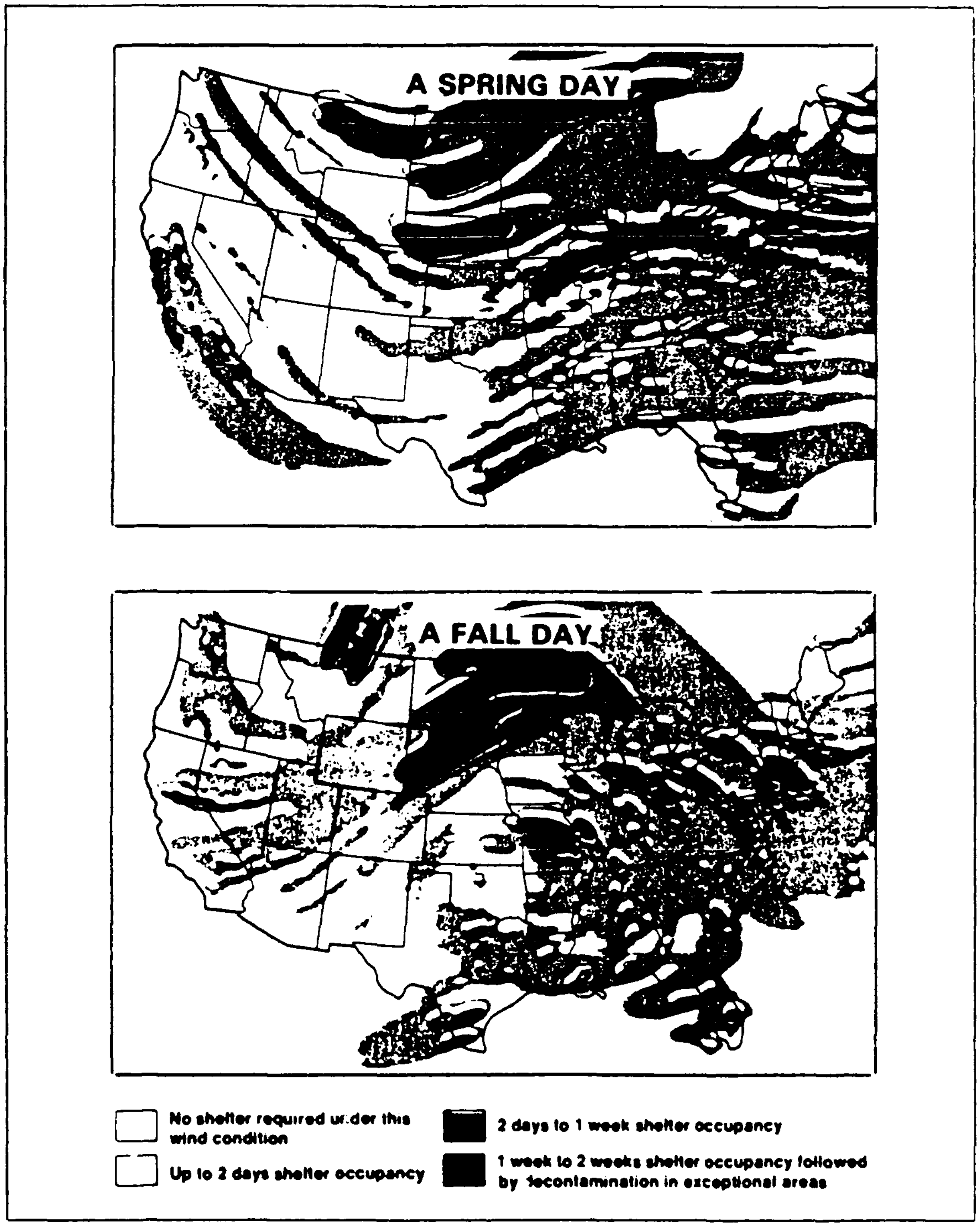


Figure 5. Estimated Fallout Patterns (11:27)

what percentage of survivors would face a given level of radiation hazard, it is more realistic to use percentage of

land area (11:273). It is important to remember that with any model there are assumptions that must be made. An actual attack could easily be more or less severe.

Table 2

Percent of U.S. Land and Population Covered With Fallout (11:272)

UNIT-TIME REFERENCE OF DOSE RATE cGy/HOUR	CUMULATIVE DOSE TO INFINITY cGy	% OF LAND AREA	% OF POPULATION
> 10,000		2	9
> 3,000	>12,000	12	33
> 1,000	> 2,000	27	56
> 300	> 500	49	79
> 100		66	88
> 30		80	93
> 10		86	95

The approximate cumulative dose to infinity depends on the fallout arrival time which is not known. Fallout arrival time of 1 hour, 7 hours, and 24 hours, are assumed for the three unit-time reference doses of 3,000, 1,000, and 300 cGy, respectively, to obtain the three entries shown. 1 cGy = 1 RAD = a unit of absorbed dose of radiation.

Radiation Time-Dependence. The model used the $t^{-1.2}$ law for the time up to six months and the $t^{-2.2}$ law after six months. The fallout arrival time t_1 is included as an adjustable parameter in the model. The war delay time t_0 is assumed to be zero. In other words, E/R assumed all weapons are detonated at a similar time after

sheltering. This is probably not realistic, but was used to overcome the uncertainty involved (11:274).

Shelter Time Strategy. The model assumed the occupant of a shelter given any PF will emerge after spending time t_2 in the shelter. Upon initial emergence from the shelter, the survivor returns to the shelter each day after spending a fraction of the day, f, outside. The fraction of the day outside was assumed to increase linearly with time until it reached $f = 0.5$ at six months after the attack, following which it was assumed to be constant. The parameters used were based on the following three considerations:

1) After initial emergence from the shelter at time t_2, the great need for food, water, and other supplies probably requires a significant time out of the shelter, leading to step 2 at time t_2;

2) The rapidly decaying fallout intensity allows progressively longer times outside the shelter, hence the liner rise after the initial step; and

3) The very rapid decline in intensity after six months makes that time an appropriate time to define the $f = 0.5$ plateau (11:274).

Model Parameters. The model described involves just four parameters:

t_1 = fallout arrival time, (1)

t_2 = shelter time, (2)

f = initial fraction of a day outside the shelter upon emergence, and (3)

PF = shelter protection factor (11:274). (4)

The fifth parameter t_0 was given to approximate the effects of a protracted war, but will be used only for comparison in this review.

The cumulative exposure dose is given by the following formula: D = Cumulative exposure dose (5)

$$D = 5D_1/PF(t_1^{-.2} - t_2^{-.2}) + 5D_1f/PF(1 - t_2^{-.2})$$

$$- 5D_1/PF(1 - t_2^{-.2}) + 5D_1C/4(1 - t_2^{.8})$$

$$+ 5D_1Ct_2(1 - t_2^{-.2}) - 5D_1f(1 - t_2^{-.2})$$

$$- 5D_1C/4PF(1 - t_2^{.8}) - 5D_1Ct_2/PF(1 - t_2^{-.2})$$

$$+ 5D_1/12 + 5D_1/12PF \quad (11:274). \qquad (6)$$

The data in tables 3 and 4 was developed to help compute the data in Table 5.

Table 3

Penalty Table
Accumulated Radiation Exposures in cGy (11:271)

MEDICAL CARE WILL BE NEEDED BY	A ONE WEEK	B ONE MONTH	C FOUR MONTHS	
A NONE	150	200	300	A
B SOME (5% may die)	250	350	500	B
C MOST (50% may die)	450	600	-	C

Table 4

Cumulative Exposure Levels Based on One Week Exposures in cGy as given in Table 3 (11:272)

	ONE WEEK	ONE MONTH	FOUR MONTHS	SIX MONTHS
LEVEL A	150	215	308	350
LEVEL B	250	358	514	583
LEVEL C	450	645	925	1050

Table 5

Dose Reduction Factors F (11:276)

CUMULATIVE DOSE DOSE TO INFINITY	PERCENT OF LAND AREA	LEVEL A *	LEVEL B *	LEVEL C *
> 12,000	12	.029	.049	.088
> 2,500	27	.14	.23	.42
> 500	49	.7	-	-

* Values taken from Table 4 assuming 6-month exposure time.

Results. First, E/R used the three cumulative doses 12,000, 2,500, and 500 cGy present over one-eighth, one-fourth, and one-half the U.S. land area, respectively, from Table 3. Next, they used the cumulative dose reduction factors: F = 0.23, F = 0.14, and F = 0.088, which have the following significance:

F = 0.23: allows survival throughout half the U.S. land area, with cumulative doses below 500 cGy, and up to 95 percent survival throughout that quarter of the land area with doses between 500 and 2,500 cGy.

F = 0.14: allows survival with no medical care for three-fourths of the land area with doses of less than 2.500 cGy.

F = 0.088: allows 50 percent survival throughout seven-eighths of the land area with doses less than 12,000 cGy (11:275).

Third, by holding three variables constant, i.e., PF = 20, t_1 = 10 hours, and t_0 = 2.5 days, to see how the other two, f and t_2 would vary, they calculated some interesting results. For F values of 0.23 and 0.14, they found that:

a) long shelter stays are unnecessary as long as the survivors spend a significant fraction of each day in shelter after initial emergence,

b) it is unnecessary to spend much time in shelters each day after emergence, if the survivor managed an initial stay as long as three weeks, and

c) if survivors initially emerge only 10 percent of each day instead of 30 percent of the day, they can shorten their time in the shelter from three weeks to one week (11:275).

Another surprising result concerned the increase in PF from 20 to 100. The PF of 100 only produces a very minor dose reduction even though the PF had increased five times. Well-sheltered survivors get a large fraction of their exposure after emergence from the shelter. Of course, in heavy fallout regions where radiation dose factors are high, the PF = 100 shelter would be tremendously better at shielding against a lethal dose. On the other hand, as Table 5 shows, a dose reduction of F = 0.14 should give excellent survival chances throughout most of the U.S. land area (11:276).

There is no substitute for high PFs in heavy fallout areas. However, for low-fallout regions, this model shows a very interesting trade-off between PF and f, the initial fraction of a day spent outside the shelter upon emergence. For example, a survivor who emerges from a PF = 20 shelter after 12 days and initially spends 10 percent of the day outside, has the same cumulative dose as one who emerges from a PF = infinity shelter and initially spends 30 percent of a day outside (11:276). This puts survival in the hands of each individual who is lucky enough, or who chooses to live in an area with a predicted low-fallout threat. With a very basic understanding of this trade-off principle, millions of civilians could control their cumulative radiation dose to maintain non-lethal levels.

Of the five adjustable parameters in the model, PF, f, t_2, t_1, and t_0, the first three can be determined by the individual survivor. He can build a shelter having a particular PF, stay in the shelter a time t_2, and emerge for a safe fraction of each day. Variable, t_1 and t_0 are generally out of the survivors control, as they are dependent on the attacker's targeting strategy. Of these two, t_2, fallout arrival time is by far the most critical. Thus, being sheltered is relatively more important for short fallout arrival times (11:277).

The principle conclusion of the Ehrlich and Ring study is that for most of the U.S. land area, fallout sheltering is feasible and would not require prohibitively long shelter times or very high PF shelters (11:278).

Furthermore, when compared to an independent study by Grant and Chester (GC), whose emphasis was more on relocation to prepared shelters, GC's results were highly consistent with ER's results (11:279).

In low-fallout areas, where the other effects of nuclear weapons are not a factor, an average citizen can take the precautions to survive. Given some very minimal training, or even just the information on the tradeoffs between sheltering and exposure time after emergence from a shelter, the probability of survival is even higher. The U.S. population can understand these principles and afford to take the wide variety of possible actions. Whether it is an unprepared basement with a PF of 10 or a high-technology fallout shelter with a PF of 10,000, both can survive with some basic knowledge which is currently available.

III. Research and Analysis - National Security Strategy and the Viability of a National Fallout Shelter Program

Overview

In the past three decades there have been many powerful and scholarly arguments for and against civil defense and a national CD shelter program. In this study I examined several of those arguments to focus on the research question - given that the technology exists to build effective fallout shelters, and given the empirical data to prove shelters save lives, why hasn't the U.S. implemented a national fallout shelter program?

Salient to question of CD fallout shelters in the U.S. is the philosophy expressed in the "National Security Strategy of the United States" (NSS), and within it, the U.S. Defense Agenda. This document is the President's summary of our national strategy, goals, and interests, and the basis for all U.S. actions to protect and defend our nation and our way of life in terms of military, economic, and political efforts (33:ii-v). These points are listed in a deliberate order in the NSS to emphasize the Bush Administration's priorities for the important issues.

The arguments listed below, both for and against a national fallout shelter program, fall into these same categories, military, economic, and political, as each applies to CD fallout shelters. The analysis begins with

the National Security Strategy, and emphasizes defense issues. Military, economic, and political arguments both for and against fallout shelters follow. Each section begins with the opponents' argument(s), followed by the proponents' position(s).

National Security Strategy

In chapter six of the 1990 NSS, "Relating Means to Ends: Our Defense Agenda," President Bush points out that consistency of military purpose and action, leading-edge technology, close cooperation with allies who share U.S. values, willingness to project force to deter aggression, and the use of forward presence have worked synergistically to successfully accomplish our goal of Soviet containment (33:22).

Four specific elements are identified and defined in the NSS as contributing to this successful Soviet containment: deterrence, strong alliances, forward defense, and force projection. The NSS defines these elements as:

> Deterrence: Throughout the post war period we have deterred aggression and coercion against the United States and its allies by persuading potential adversaries that the cost of aggression, either nuclear or conventional, would exceed any possible gain... "Flexible response" [as a tool of deterrence] demands that we preserve options for direct defense, the threat of escalation, and the threat of retaliation. (33:22)

This is where the arguments for and against CD fallout shelters apply - to the concept of deterrence. Opponents argue that deterrence has been successful for over thirty

years without fallout shelters - a powerful argument with three decades of momentum to back it up. Proponents argue that fallout shelters strengthen deterrence by diminishing an enemy's ability to coerce the U.S. by threatening our civilian population. Deterrence, however, is only one of the elements of Soviet containment. The NSS also lists strong alliances, forward defense, and force projection as key elements of U.S. containment efforts. The NSS also defines these.

> Strong Alliances: Shared values and common security interests form the basis of our system of collective security. Collective defense arrangements allow us to combine our economic and military strength, thus lessening the burden on any one country.
>
> Forward Defense: In the postwar era, the defense of these shared values and common interests has required the forward presence of significant American military forces in Europe, in Asia and the Pacific, and at sea. These forces provide the capability, with our allies, for early, direct defense against aggression and serve as a visible reminder of our commitment to the common effort.
>
> Force Projection: Because we have global security interests, we have maintained ready forces in the United States and the means to move them to reinforce our units forward deployed or to project power into areas where we have no permanent presence... (33:22)

A more subtle message in the overall strategy is the effort to deter aggression and, when necessary, to employ military force, as far away from U.S. soil as possible. If we can influence the location of our armed conflicts by projecting military force outside the U.S., the probability of having North American battlegrounds is diminished, as is our need for CD.

Finally, this section of the NSS explains that other factors also contribute to the four elements of our defense policy.

> These elements have been underwritten by advanced weaponry, timely intelligence, effective and verifiable arms control, highly qualified and trained personnel, and a system for command and control that is effective, survivable, and enduring. Together they have formed the essence of our defense policy and military strategy during the postwar era. (33:22)

There is no mention of CD or any type of shelters in the National Security Strategy. The emphasis remains on strong offensive forces designed to deter aggression through the threat of retaliation. This provides some insight as to why the U.S. has no CD fallout shelter program. The public positions taken by our highest-level leaders and policy makers indicate that they do not make fallout shelters a high priority of national security. On the contrary, first on the U.S. list of overall national security priorities is deterrence of nuclear attack by maintaining strong and high-technology offensive weaponry, and the resolve to use it if attacked. The President asserts in the NSS that even though U.S.- Soviet relations are improving, we must be ready to react to any crisis or reversal of this trend with strong nuclear offensive forces.

> Deterrence of nuclear attack remains the cornerstone of U.S. national security. Regardless of the improved U.S.-Soviet relations and potential arms control agreements, the Soviets' physical ability to initiate strategic nuclear warfare against the United States will persist, and a crisis or political change in the

> Soviet Union could occur faster than we could rebuild neglected strategic forces. A START agreement will allow us to adjust how we respond to the requirements of deterrence, but tending to those requirements remains the first priority of our defense strategy. (33:22)

Specifically relating to strategic defense, the NSS looks for a move away from purely offensive weapons, which maintain deterrence, to a shared responsibility with the Strategic Defense Initiative (SDI) defensive systems which propose a level of deterrent capability.

The SDI technology is viewed as a deterrent, given that it works as advertised, because its space-based systems would intercept and destroy enemy offensive weapons before they can strike U.S. targets. Thus, if an enemy of the U.S. believes he cannot achieve a minimum probability of success with his offensive nuclear weapons, and he knows the U.S. will retaliate, he should be deterred from attacking the U.S. This is deterrence. It has been accomplished for the past 30 years with large numbers of offensive weapons (enough to survive an initial attack and retaliate). With SDI, the number of offensive weapons could be significantly reduced while a relatively stable deterrent is maintained with the technology of the defensive systems. Furthermore, the SDI could help prevent a disaster caused by an accidental launch, or a terrorist or third world attack - making the U.S. a safer place. President Bush expresses this philosophy in the NSS:

> Looking to the future, the Strategic Defense Initiative offers an opportunity to shift deterrence

> to a safer and more stable basis through greater reliance on strategic defenses. In a new international environment, as ballistic-missile capabilities proliferate, defense against third-country threats also becomes an increasingly important benefit.
> ... Initial strategic defenses would also offer the United States and its allies some protection should deterrence fail or in the event of an accidental launch. (33:24)

The argument that effective deterrence is accomplished only through high-technology offensive and defensive weaponry is strong. It is supported by over 30 years of successful deterrence. One can understand why few federal planners are anxious to add CD fallout shelters to a system that already works.

Shelter Proponents' Strategy

Shelter proponents have to agree that offensive nuclear weapons have maintained deterrence, but argue that the plan to rely upon them alone is flawed. The current deterrent strategy presupposes that an accidental launch will never occur, and that the U.S. is dealing with adversaries that are rational; otherwise, we could be vulnerable. Proponents believe a national fallout shelter system provides the extra level of safety needed should an accidental or irrational event occur, and that it increases the survivability of our civilian population should deterrence fail. Thus, shelters would help to achieve the President's top priority, "The survival of the United States as a free and independent nation, with its

fundamental values intact and its institutions and people secure" (33:2).

SDI is a significant technological breakthrough. Granted, there has been heated debate by some very brilliant scientists over its feasibility and practicality. More importantly, there is evidence the U.S.S.R. thinks it will work. Thus SDI has the ability to halt or slow the offensive nuclear arms race of the past three decades. Even though SDI is only in research and development, its deterrent "muscle" is already being felt.

In his White Paper titled, "The Air Force and U.S. National Security," Secretary of the Air Force, Donald B. Rice, asserts that the U.S. has clearly won the cold war. One of the key elements, which led the Soviets to concede that they have lost the arms race, is the technology of SDI. SDI provides enough uncertainty about the success of a nuclear attack upon the U.S. to make the probability of success unacceptable (37:3).

Shelter proponents argue that SDI is significant, but not a complete defense by itself. SDI defensive weapons cannot intercept all incoming enemy weapons. However, when a national fallout shelter system is added to SDI, the U.S. will have a credible deterrent capability without the need for large offensive nuclear forces. Furthermore, if some future technology breakthrough renders SDI ineffective; if there is an accidental nuclear launch; or if

deterrence fails against terrorism or an enemy leader who does not fear the retaliation of U.S. offensive weapons; the fallout shelter system would provide a degree of protection for U.S. civilians not currently available.

In 1986, General Daniel O. Graham, director of High Frontier, a private organization promoting SDI, was quoted at the American Civil Defense Association's annual meeting as saying, "There is a very definite linkage between civil defense and SDI... They are the same thing... protection of the American people against nuclear attack" (30:43).

Conrad V. Chester, director of the Oak Ridge National Laboratory, postulated that a 90 percent effective SDI system, coupled with blast shelters hardened to 50 psi could limit fatalities to 5.3 million following a major nuclear attack. He contrasted the 5.3 million with 60 million potential fatalities if SDI alone were deployed (30:43). Fallout shelters would not be as effective in high-risk areas as blast shelters, but the potential for saving lives in lower-risk areas is very good.

These and other predictions are generally based on the best estimates of enemy weapon types, yields, and detonation plans; probable U.S. targets; populations of target areas; and the capabilities of SDI. The data is usually entered into a mathematical model to determine survivability. There are so many variables and unknowns that it is difficult to be precise; however, a predicted difference

of several million lives saved is reason enough to pursue a fallout shelter option. Furthermore, the knowledge that with a fallout shelter system the U.S. cannot be easily coerced, helps to ensure the free and independent nation President Bush mentioned.

This analysis of the NSS defense agenda has focused on the role of offensive and defensive military options in our nation's defense, and questioned the possible role of fall-out shelters. The NSS also develops economic and political objectives. This study will follow the same pattern by examining military, economic, and political arguments about fallout shelters. The military arguements are next.

Military Considerations

The military arguments about fallout shelters center around three topics: the strategic defense strategy of counterforce strike or "limited" or "flexible" nuclear war; possible increased tensions between superpowers if building fallout shelters is perceived as an act of aggression or preparation for war; and the rapidly changing geopolitical and economic state of the U.S.S.R. These changes are examined because of their possible impact on the threat of nuclear war.

Counterforce Strike. One of the large philosophical changes in nuclear military strategy and planning was the move from historical strategies, such as massive retaliation and mutual assured destruction, to the current strategy of

counterforce strike (CF). This strategy is also known as counterforce attack, counterforce missions, limited nuclear war, or flexible response. Whichever term is used, the purpose of CF is to destroy the military capabilities of the opponent, including nuclear and non-nuclear forces and the industrial base which supports them (41:36). It is flexible and can be used for a first strike, retaliation, or most any other option. Since an opponent's strategic forces represent the greatest threat, they are considered the highest-priority targets for CF missions (41:36).

An all-out nuclear war between the U.S. and the U.S.S.R. would destroy the urban areas of both countries and thereby the infrastructure that makes them modern industrial states. Military theorists and planners therefore conclude that such a deliberate war would be the ultimate act of folly (8:3). Following this reasoning, U.S. policy was changed during the 1970s to exclude the targeting of populations per se. Targeting military facilities was estimated to cause much lower collateral civilian casualties than attacks on population centers, while accomplishing the U.S. military objectives and providing an equivalent level of deterrence (8:3).

Many defense analysts argue that threatening to destroy a variety of military targets deters limited aggression more effectively than threatening to attack cities, because threats against military targets are less likely to elicit a devastating retaliatory attack against the cities

of the attacker (41:36). The argument continues that modern nuclear weapons with multiple warheads, each capable of very accurately destroying a separate target, have made the counterforce strategy possible and decreased the collateral threat to our cities (41:36).

Following this premise, shelter opponents conclude that if U.S. populations are not being held at risk, there is no real need for shelters.

Proponents question the level of civilian immunity to attack in a counterforce strategy. Dr. Frank Von Hippel, professor of international affairs at Princeton University, and noted author on strategic nuclear arms, is convinced that strategic CF missions do not provide a more credible deterrent by threatening military targets instead of civilian cities. He bases this assessment on a hypothetical attack on the U.S., which includes 3,000 warheads on 1,217 military facilities with a yield of 1,300 megatons and all but about 100 targets were missile silos or launch-control centers (41:37-38). Interestingly, this is well within the capabilities of START-negotiated reductions. The probable list of targets in the U.S. included major nuclear-weapon depots and bases (both ICBMs and strategic bombers), tanker bases to support the bombers, and submarine bases. In this study he and his co-authors say:

> Our calculations suggest... a large-scale attack on strategic forces would cause so many civilian casualties that it would be difficult to distinguish from a deliberate attack on the population. (41:36)

The reason for this statement is that many of these military targets are co-located with large cities and population centers. For example:

> Tanker aircraft are based at airports near Chicago, Milwaukee, Phoenix, and Salt Lake City; Navy bases for nuclear-armed vessels are situated in the San Francisco Bay and at Long Beach (near Los Angeles), with another planned for Staten Island in New York Harbor; key command posts are in the vicinity of Washington D.C., with Navy radio transmitters at or near Jacksonville, Sacramento, and San Diego. (41:37)

Attacks on these facilities alone would cause serious civilian losses. Dr. Von Hippel's study estimates between 11 and 29 million civilian casualties if the 101 highest-priority U.S. military-industrial factories were also targeted. This is the case because they are located in cities like Boston, Detroit, and Los Angeles (41:42). Blast shelters would provide the best protection in these areas, but fallout shelters in the outer blast limits and down wind of these locations would save many thousands of lives. Additionally, fallout shelters downwind of the six ICBM launch complexes could save millions of lives (see Figure 5).

Increased Tensions. Another military argument against fallout shelters is made by those who believe building shelters will increase tensions between the U.S. and the U.S.S.R. For example, Dr. Irwin Redlener, a spokesman for the Physicians for Social Responsibility, testified before Congress saying, "... the provision of a civil defense evacuation plan indicates that we are ready for nuclear

war, and that the more ready we are for nuclear war, the more likely is the ultimate occurrence" (38:45). Furthermore, Louis Berres, an expert on U.S. stra egic forces, has stated, "A U.S. resort to crisis relocation planning would almost certainly be viewed as a provocative act by the Soviet Union, perhaps even confirming their oft-stated fears of a U.S. first strike" (2:87).

Crisis relocation is the CD program implemented by Presidential Directive (PD-41) in 1978. It is an effort to save lives, in the absence of shelters, by evacuating large cities in the high-risk areas to host regions in lower-risk areas when strategic warning of an impending attack is given (29:7). Plans for crisis relocation and building shelters are seen as equivalent actions.

The proponents' position is very different on this point. They argue that fallout shelters are the least threatening strategic defense compared to past, present, and future offensive and defensive research programs and fielded weapons. The anti-ICBM technology of SDI, the stealth technology of the B-2 bomber, and the Peacekeeper and small mobile ICBM technology are threatening enough to the Soviets. Compared to these programs, the implementing of CD fallout shelters is a very small threat. On the contrary, in the unlikely event of a nuclear attack, fallout shelters could save millions of lives.

Changing Threat. A third argument related to the military evolves around current world conditions.

Opponents of CD fallout shelters argue that economic, social and political problems in the U.S.S.R. over the past 18 months have weakened their military preparedness and softened the strategic nuclear threat. The Soviet and Warsaw Pact military forces are no longer united and have internal problems such as serious shortages in officer and enlisted housing which causes very low morale (7:29). This is a significant change for U.S. and NATO planners. For over three decades the effort to deter or defeat a Soviet invasion of Western Europe has shaped almost everything about the U.S. military establishment, manpower requirements, weapons design, budget requests, and more (6:16). For over 20 of those years, American and NATO planners have prepared for a mass invasion by Soviet and Warsaw Pact tank and armored columns across the Fulda Gap into West Germany, starting a conflict that could quickly escalate into a nuclear war (6:16).

Suddenly, and quicker than anyone could have guessed, all this has changed. Many Warsaw Pact countries are making a break from Communist rule, and have asked the Soviet military to leave their countries. Soviet troop withdrawals from Warsaw Pact countries like Hungary, Poland, Czechoslovakia, and Rumania, have begun or are imminent. Future withdrawals from East Germany, as unification of the two Germanys proceeds, with incredible speed, is also forthcoming (28:50). Troubled by internal dissent and economic failure, the Soviet Union has proposed uni-

laterally reducing its army by 500,000 soldiers (6:17). "The Warsaw Pact, for all practical purposes, is dead as a military alliance," according to top presidential advisors (6:17). All of these events play significant roles in the Soviet military's strategic and conventional force strategies.

Additionally, the recent signing of the Intermediate Range Nuclear Forces (INF) Treaty between the U.S. and U.S.S.R. removed an entire class of nuclear weapons. This class of weapons was threatening to the Soviet Union because the U.S.S.R. considered them first-strike weapons with little deterrent value (2:82). Furthermore, the Strategic Arms Reduction Talks (START) negotiations are steadily progressing and capable of reducing U.S. and Soviet nuclear arsenals by up to 50 percent (35:30). All these events provide shelter opponents with evidence for their argument that nuclear war is a reduced threat, and that a national fallout shelters are not necessary.

Shelter proponents agree that the current political, social, and economic instability currently present within the U.S.S.R. and among its allies in the Warsaw Pact has weakened the Soviet military. Although many analysts are quick to point out the weaknesses in the Soviet military, the President, as Commander-in-Chief of all U.S. military strategic forces, believes that Soviet strategic weapons are as strong and threatening as ever. President Bush

stated in February 1990, "We see little change in Soviet strategic modernization" (6:17). In his June 11, 1990 press conference, he said, "It is difficult to consider economic aid to the Soviet Union when they continue to have ICBMs targeting our cities" (3).

Proponents argue that the decreased stability of the Communist Party raises questions about their control over the powerful Soviet military, and over well-equipped but unpredictable military clients, such as Iraq and Libya. The Soviet military might be tempted to seize control of the less stable Soviet government, an act that would increase both tensions between the superpowers and the threat of nuclear war.

Furthermore, the August 1990 invasion and annexation of Kuwait by the powerful Iraqi army, armed with sophisticated Soviet and French weapons, poses a great potential threat to Western nations. It is not a threat because Kuwait was necessarily of strategic value to the West (although Kuwait controlled over 90 billion barrels of world oil reserves before they were invaded), but that no force could easily oppose the well-trained, well-equipped, million-man military of Iraq (10:22). And, as the U.S.S.R. also condemned the Iraqi action, the invasion illustrates how a weakened polar alignment of superpowers, no longer willing or able to exert controlling influence over military clients or allies, can make the world a much more

dangerous place. A new defense era has arrived. This period provides the opportunity for a ruthless leader with ballistic-missile capability, such as Iraq's Saddam Hussein, to threaten or coerce the U.S. because he may not have a rational fear of U.S. nuclear retaliation. If this condition developed, the concept of deterrence could be ineffective and the U.S. population would be at risk (10:25).

These changes are all very real and require careful examination before we can dismiss the Soviet nuclear forces or other nations' military forces as threats. Additionally, as conventional force and strategic weapons reductions are negotiated and implemented, the U.S. must be careful to ensure that a crisis or change of foreign national leadership does not return the U.S. to previous levels of threat. James Blackwell, a military expert at the Center for Strategic and International Studies in Washington, said "We need at least another year to determine whether the Soviet military restructuring is irreversible" (6:18).

Proponents argue that the implementation of CD fallout shelters would be a simple and effective hedge against the uncertainties of future world threats.

Economic Considerations

The common economic argument against a national fallout shelter program is that shelters are too expensive to be practical. Despite a variety of clever plans to reduce the

cost per shelter space, when the cost of one shelter space is multiplied by the approximately 250 million people in the U.S., a shelter system becomes a very large expense.

The historical foundation for this argument began in the early 1950's. The Federal Civil Defense Act of 1950 authorized the Federal Civil Defense Administration (FCDA) to "provide for the sheltering and evacuation of the population where appropriate" (14:2). In its first Congressional appropriation request, the FCDA asked for $403 million as the initial installment of a $3 billion civil defense program to establish a nationwide shelter system. Congress approved only $31.75 million; less than ten percent (14:2).

The next year, the FCDA director faced the Congressional appropriations committee and demanded $300 billion to provide a comprehensive U.S. civil defense system. Millard Caldwell, the FCDA director, an ex-Governor with no civil defense background, made some monumental mistakes with Congress. He was ill-prepared to answer basic questions about the new system, yet insisted on building nationwide hardened underground nuclear blast shelter facilities for every man, woman and child in the U.S. - an unnecessary and unrealistic plan (14:3).

The Congressional committees wasted no time rejecting the appropriation and argued, "... the expenditure of even a few paltry millions for civil defense would be foolish

given the fact that it would take $300 billion [an impossible sum in 1950s dollars] to provide a merely adequate system" (14:3).

The appropriations committee members had formed an unfavorable attitude toward fallout shelters. They mistook Mr. Caldwell's "ultimate shelter" proposal (a super-hard deep underground nuclear blast shelter system) for a basic system that was incorrectly interpreted as "merely adequate." Mr. Caldwell had proposed a top-of-the-line system and Congress thought it was only a marginal system at top-of-the-line prices. The idea of spending that much money for what they considered an inferior system was quickly dismissed.

Another reason for an unfavorable Congressional opinion of CD shelters was caused by the FCDA director's combative repetition of the same proposal for several years despite the Congress's rejection in successive years (14:4).

The Congressional appropriations committees under every administration from President Truman forward have cut civil defense requests to a fraction of each budget request (14:4-20). For example, in October of 1963, following the tensions of the Berlin Airlift crisis and the Cuban Missile crisis, the House Appropriations Subcommittee reduced the Office of Civil Defense's (formerly FCDA) FY 1964 budget request from $346.9 million to $87.8 million (14:10). Following weeks of Congressional testimony by dozens of

experts who favored a fallout shelter system, Albert Thomas, Chairman of the House appropriations subcommittee stated: "unlike the Herbert subcommittee, we haven't changed our minds. We're not building any fallout shelters, period" (14:11).

The current economic environment of deep budget cuts and fiscal belt-tightening will pose a difficult obstacle for a fallout shelter program. Vigorous efforts to comply with Gramm-Ruddman-Hollings legislation which requires a balanced federal budget by 1992 provide shelter opponents reason to argue against funding the expense of a national shelter program. Why fund fallout shelters when military budgets face projected cuts of 2.6 percent in 1991 with military forces reductions of 25 percent by 1995 (6:19)?

Proponents realize that asking for federal funds to construct shelters for all 250 million Americans is not practical or possible. They argue that funding for 90 million fallout shelter spaces to accommodate the percentage of civilians estimated to live in low-risk areas of the U.S. is more reasonable, but realize it will be difficult to obtain. To accomplish economic support, proponents propose three strategies:

First, the number of fallout shelter spaces available increases dramatically with the dual-use concept -- public buildings that are designed to serve as a fallout shelters during emergencies.

When shelter space is designed into public and private buildings it adds only a small fraction to the building cost when compared to single-use shelters. In Civil Defense Shelters: A State-of-the-Art Assessment, Chester and Zimmerman say:

> Slightly altering new construction to make maximum use of features which would have been constructed in any case, such as basements, is called "slanting." This technique is by far the most cost-effective approach to developing shelter. (5:ix)

Second, extensive surveys can be accomplished to identify existing buildings suitable for fallout shelter dual-use for much less than construction costs. In 1963, a government survey of possible shelter space successfully identified over 110 million spaces in existing buildings, both public and private (14:11). These surveys could be updated at a fraction of the cost of new shelter construction.

Third, home fallout shelters are owner financed. With public service training, many citizens can develop fallout shelters in their homes. This is possible at a fraction of the cost of a stand-alone fallout shelter, and at little or no cost to the federal government. Chester and Zimmerman estimate that "Fallout shelters built into new masonry construction may cost only about $50 per space" (1985 dollars) (5:ix). As previously pointed out in this study, all 90 million civilians who can benefit from fallout shelters in an attack do not need new shelters. Many possible shelters

already exist, or can exist with little modifica-tion to existing structures.

To develop this argument, assume that all 90 million civilians in low-risk areas needed new shelters (an unrealistically high number since many shelter spaces may already exist in public buildings and private homes). Next, assume $50 per shelter space of new masonry construction. 90 million spaces times $50 is approximately $4.5 billion. To put this amount in perspective, compare it to other government expenditures. $4.5 billion is 37 percent of the $12.1 billion spent for the Bradley M2 fighting vehicle; 140 percent of the $3.2 billion spent on the Maverick air-to-ground missile; and 15 percent of the $31.5 billion spent on the Aegis naval command and control system (42:25-26). This argument is stronger considering the Bradley, Maverick, and Aegis are listed as possible U.S. military cancellations next budget (42:26). To put the cost of fallout shelters in perspective with SDI, compare the estimate of $4.5 billion for fallout shelters to the $50 billion estimated cost of SDI; and Congress will continue to fund SDI research and development this year (4:24).

Economic proponents conclude that a national fallout shelter system is something the U.S. government can afford to implement. Our national leaders must determine if there are valid reasons to implement a fallout shelter program. This is also a political question, which is the next area of discussion.

Political Considerations

Historically, there have been strong political arguments both for and against CD and fallout shelters. Political arguments are often emotionally charged and based upon feelings as much as on facts. When the influence of world, national, state, and local events, plus regional preferences and biases are added to political arguments, they can become very complex, even if they appear simple. For example, in 1961, President Kennedy gave a public speech on what private citizens could do to enhance civil defense. As Dr. Blanchard explained, "the speech was ambiguous, but when combined with the Berlin Crisis atmosphere, it produced what was known in Washington as the fallout shelter "scare" (14:7). Although it was unintentional, his political speech, coupled with world events, had caused a panic.

This section presents the political arguments for and against fallout shelters as they apply to only one shelter topic - the public perception of survivability.

Negative Perceptions. An emotional argument against a national fallout shelter program is the belief that given the destructive ability of nuclear weapons, and given the large inventories of nuclear weapons in both the U.S. and U.S.S.R., if a major nuclear attack on the U.S. occurs, very few Americans will survive.

This is not an isolated opinion. According to Dr. Timothy Ashby, who quotes a Gallup poll published in the

5 October 1981 issue of <u>Newsweek,</u> almost half of those surveyed do not believe they can survive a nuclear war. He said:

> Forty seven percent of those Americans polled said they tried not to think about the unpleasant topic of nuclear war at all. Those people who prefer not to think about the subject of nuclear war probably do so because they believe that nothing can be done to survive it. (1:50)

Dr. Jane Orient, President of Doctors for Disaster Preparedness, has also witnessed this argument. In an April 23, 1988 symposium speech titled, "Medical Preparedness and Nuclear War," she described a commonly expressed argument that there are enough nuclear weapons in the world to kill everyone 100 times over, and then described another oft-heard opinion.

> If you ever read or listen to the media, you are familiar with this opinion. It goes like this: if somebody ever pushes the button, they'll blow up the world, and everybody will die. (34:186)

A companion belief, making forthright discussion of fallout shelters still more difficult, is that even if someone survives the initial nuclear effects of war, the quality of life in a post attack period would not be worth living. In their publication, <u>Recovery from Nuclear Attack,</u> FEMA also quotes the opponents' argument:

> For the most part, opponents [of CD] dismiss the claims of survivability as only temporary and of little consequence. Ultimately, they argue, the longer term effects of the [nuclear] attack will kill off those who survive initially and render any prospects of societal recovery meaningless. (25:2)

This FEMA author also asserts that the overwhelming nature of nuclear war may frighten many people into believing they cannot survive. He states:

> There is no doubt that if a large-scale nuclear exchange should ever occur, the result would be a massive disaster for the societies involved. The death, suffering, misery and long-term consequences of various types would have few if any parallels in human experience -- and certainly none in the history of the United States. (25:preface)

Shelter opponents conclude that ultimately, no one will survive a nuclear war. It is therefore folly to use valuable U.S. resources for fallout shelters.

Survivability. Proponent agree that the massive destructive forces of nuclear weapons are well documented. It is clear the superpowers are also agreed that nuclear war is not winnable and should not be fought. However, many have people incorrectly concluded that if a nuclear war is not winnable, it is also not survivable. Shelter proponents argue that this logic is wrong. They believe the argument is not only incorrect, it is also dangerous because it discourages those who would otherwise take the common sense steps that would improve their chances to survive (25:1).

Many scholars and nuclear weapons experts agree that even major attacks are survivable. There is both historical evidence and current models which provide adequate evidence of good to excellent probabilities for surviving a nuclear attack, depending on the size and type

of attack, and the amount of protection available for the population.

In their 1986 study, "The Consequences of a Limited attack on the United States," William Daugherty and two colleagues calculated the U.S. casualties resulting from several levels of attack, ranging from 100 to 1340 megatons of nuclear yield, and ranging from military targets only to major populated cities. Their results predicted that in a worst-case scenario involving attacks on major cites, up to 66 million people would be killed (8:24). Although this is unthinkably horrible, it also means that over 180 million people in the U.S. could survive. More people would survive with adequate shelter and warning time but, without fallout shelters many survivors would be exposed to lethal doses of radiation from the fallout that would shortly follow (8:25).

In addition to the scholars quoted, many of our national leaders think CD is a way to increase survivability. Congressmen have written laws to enhance national CD efforts and both Presidents Carter and Reagan signed directives to improve U.S. CD efforts in a move to increase survivability.

In September 1978, President Carter signed Presidential Directive, PD-41, on CD policy authorizing crisis relocation. His third goal instructed, "Provide for some increase in the number of surviving population ... (29:8S). In 1982, President Reagan executed a new seven

year plan to upgrade civil defense. His third of his four goals called for, "the survival of a substantial portion of the U.S. population" (29:8S).

In Congress, proponents have also stressed the role of CD in U.S. strategic defense policy, where in 1981, Representative Ike Skelton (D) Missouri, testified:

> During the 96th Congress, I offered a civil defense amendment which was signed into law. This amendment, for the first time in our Nation's history, made civil defense part of our strategic defense policy. (29:8S)

Political proponents argue that with both scholars and U.S. political leaders convinced that nuclear war is survivable, the argument in favor of a national fallout shelter system has merit.

The arguments discussed which surround the public preceptions of survivability are complex and emotionally charged. Nevertheless, the best calculations and predictions of nuclear weapons experts, with the concurence of several Congressional leaders and the last two U.S. presidents, demonstrate that millions of Americans can survive a major nuclear war. Furthermore, the number of survivors can be increased with a national fallout shelter program. When the facts about survival are separated from and compared to the emotional arguments of a nuclear doomsday, a much stronger case is made for survival.

IV. Conclusions and Recommendations

Research Summary

The question of whether or not the U.S. should have a CD fallout shelter system is an old and on-going debate. In this study I focused on the research question: given the U.S. has the technology to design and build effective fallout shelters, and given sufficient proof that fallout shelter will protect against radioactive fallout, why hasn't the federal government implemented a national fall-out shelter program to protect its civilian population from nuclear attack, should deterrence fail?

The initial literature search established the basic CD strategies of the U.S. and U.S.S.R. and the U.S. CD activity since the late 1950s. There is a significant difference between U.S. and Soviet emphasis on CD, based on differences in defense philosophy. Their CD efforts are maximum while ours are minimum.

Nevertheless, CD shelter design is considered a mature technology in the U.S. There is adequate evidence to show that blast shelters were an effective form of civilian protection during the intense Allied bombing of World War II (WWII) Germany. In the 1950s and 1960s the U.S. and U.S.S.R. conducted significant amounts of research to develop the technology to upgrade the WWII-vintage shelters to withstand the force of nuclear weapons. Additionally,

the technology to design and build adequate fallout shelters was developed. Since the physical properties of nuclear weapons do not change except to vary in yield, this technology was developed to maturity by the late 1960s.

The physical properties of nuclear weapons are a formidable challenge for shelter designers to protect against. They are defined as blast overpressure, high winds, shock, thermal radiation and fires, initial nuclear radiation, electromagnetic pulse, and radioactive fallout. All of these effects would require blast-quality shelters in the high-risk areas of the U.S., except for radioactive fallout. Since fallout is the primary danger for many areas of the U.S., up to 85 percent of the country would be adequately protected by fallout shelters in the event of a nuclear war.

There are many possible reasons why the U.S. remains a nation without a national fallout shelter program. Any discussion of fallout shelters must take into account the continuing threat of nuclear attack. The possible end of the cold war does not eliminate Soviet nuclear arsenals nor their modern and accurate strategic weapons targeting the U.S. military. The U.S. has the technology to shelter its population, and there is a federal agency established to administer CD programs, but the U.S. remains vulnerable, should deterrence fail. This study examined some possible reasons in this study within the language of the National

Security Strategy (NSS), and by focusing on the military, economic, and political arguments both for and against.

The NSS emphasized defending our nation through deterrence by maintaining strong, high-technology strategic offensive and defensive forces. This strategy is moving toward more high-technology defensive forces with programs like SDI, but the current plans do not include a fallout shelter system.

Military shelter opponents argue that due to our counterforce strategy which targets only military facilities, the weakening of the Soviet military as a result of the rapid and destabilizing changes in the Soviet society, and the belief that building fallout shelter would be interpreted by the U.S.S.R. as an act of U.S. aggression, fallout shelters are not needed, and should not be built.

Economic opponents argue that the federal government cannot afford to fund the design and construction of fallout shelters; while political opponents argue that no one can survive a nuclear war, so fallout shelters are a poor use of valuable resources.

Proponents of a U.S. national fallout shelter system argue that even though the language of the NSS does not specifically recommend fallout shelters, a national fallout shelter system used in harmony with U.S. strategic offensive and defensive forces is the most cost-effective and technology resistant (technological breakthroughs will not

easily negate the system) of any U.S. system, either fielded or planned.

Military shelter proponents argue that there is an immediate need for a national fallout shelter system since:

1) The counterforce strategy - military targets co-located with large population centers - places millions of civilians in danger;

2) The weakening of the strong bipolar world allows third world countries to coerce without constraints;

3) Soviet strategic forces have not weakened; and

4) Fallout shelters are the most cost-effective, easiest to implement, and least threatening of all defense programs.

Answering the economic arguments against fallout shelters, proponents argue that the U.S. has a huge untapped resource of public and private buildings that can provide effective low-cost fallout shelters; a fallout shelter system is a less expensive option than most offensive and defensive weapons systems; the DoD has already spent more money for failed weapon systems than is needed to fund a complete national fallout shelter system; and home fallout shelters are effective protection, but cost the federal government next to nothing because they are owner financed.

To counter political arguments against fallout shelter, proponents agree that nuclear war is terribly destructive, but argue that it is survivable. A national

fallout shelter program will save millions of additional lives that would otherwise be lost without shelters. There was no evidence in either the National Security Strategy, or the military, economic, and political categories against fallout shelters that could not be answered in favor of a national fallout shelter program.

Research Conclusions

My research uncovered no definitive answer to the research question - why hasn't the U.S. implemented a national CD fallout shelter program. In fact, many more questions were raised than answered. Some of these additional questions are listed in the last section below.

The opponents' position in the fallout shelter question has tremendous momentum since deterrence without fallout shelters has been successful for over thirty years. The proponents' position that fallout shelters are a simple technology, affordable, and have the potential to save millions of lives in a crisis is also strong. This dichotomy leads one to question if these two factions are talking to each other in an effort to resolve this issue.

There is ample evidence in the Ehrlich and Ring model to support the concept of home fallout shelters as a viable defense strategy. The fact that the studies of other respected researchers in this field, such as Chester and Zimmerman, Grant and Chester et al., and Von Hippel et al.,

have similar conclusions, plus the volumes of material available from FEMA which also support fallout shelters, provide additional strength to this argument.

This very encouraging research (the Ehrlich and Ring model) concluded that in the event of nuclear war, millions of U.S. civilians can survive with little more than the minimal shelter of an unprepared basement, given the basic instruction on the critical ratio of time in shelter to exposure rate. This is exciting because it is feasible, affordable, and manageable. It also demonstrates that survival is possible without dependence on any expensive government program(s) that may or may not get funded.

In low-risk areas, where other nuclear explosion effects are not a factor, and given some very minimal training, or the information on the tradeoffs between sheltering and exposure time after emergence from a shelter, an average citizen can easily take the necessary precautions to survive. The principles are easy to learn and understand, and the average person can afford to make the necessary preparations to make the plan work. Whether the fallout shelter is an unprepared basement with a PF of 10, or a high-technology shelter with a PF of 10,000, both can survive with some basic knowledge of the relationship between shelter time and exposure to radiation. This information is currently available.

Finally, one of the most poignant arguments in favor of CD and survival from a nuclear attack was made by

Dr. Jane Orient in her speech mentioned earlier in this study. She was addressing the CD opponents' viewpoint when she quoted two arguments, and then completed each with her own interpretation of the corollary. Her comment cuts to the very core of the CD fallout shelter question. This simple insight also provides justification for federal sponsorship of the implementation of a national fallout shelter program. She said:

> Strangely enough, the people who worry the most about nuclear war tend to be the most vehemently opposed to civil defense. Besides the cost argument, there are basically two others:
> 1) We couldn't save everybody. (Corollary: therefore, we shouldn't try to save anybody.), and
> 2) The nation with the fewest survivors would be better off, because there would be fewer people having to share the remaining resources. (Corollary: human lives don't count as a resource, or are far less important than other resources). (34:190)

The U.S., built on the philosophical foundation of basic human rights such as life, liberty, and the pursuit of happiness, has the legal and moral obligation to attempt to protect every citizen from foreign military aggression. This study asserts that our human resources are our most valuable national resources, and that should our history of successful deterrence ever fail, home fallout shelters and the knowledge of time-in-shelter to exposure-rate ratios will save millions of lives that would otherwise be lost.

Recommendations

1. FEMA should implement a public service training program to teach the public, in a non-threatening way, that

nuclear war is survivable; that a minimum shelter facility, equivalent to an unprepared basement or internal section of a highrise building, is sufficient to survive the radiation in most fallout concentrations, if used properly; that the amount of time required in a shelter can be flexible, as long as the ratio of exposure to shelter time is maintained within correct parameters; and that being prepared for uncertainty is the safest way to maintain our national security.

2. FEMA should encourage the public to store three weeks worth of emergency non-perishable food, water, medical supplies, and toiletries for use in a private home shelter, or to take with them to a public shelter. These supplies can be acquired over time to minimize any financial hardship, but should be rotated regularly to avoid spoilage or waste. A three-weeks supply would allow sufficient shelter time for fallout radiation to drop to safe levels, in most cases.

3. Congress should fund FEMA to reaccomplish a national survey to identify the number of potential shelter spaces available in public and private buildings. This analysis should include both high and low-risk areas. When the survey is complete, FEMA must ensure the identified spaces are clearly marked, and that civilian populations know where they are, and how to use them. I do not recommend stocking the shelters, since this is expensive, hard to manage, and extremely difficult to keep current.

4. Congress should enact legislation which emphasizes dual-use design in all new building construction. This can be implemented in both public and private buildings. Dual-use design should be required in all public buildings by regulation, and strongly encouraged in private building through dual-use specifications in all building codes. Federal incentives could also be offered for voluntary compliance with programs such as tax breaks or credits, or federal rebates.

5. Congress should inact legislation which authorizes the IRS to offer tax breaks to homeowners who design fall-out shelters into new home construction, or who add a shelter to an existing home.

Additional Research Questions

Many additional questions were raised in this study. Any of these would make a good follow-on topic for research.

a) Since both the opponents and proponents of a national fallout shelter system have strong and reasonable arguments, what evidence is there that they are talking to each other?

-- Could these questions be debated openly in some forum?
-- Could the their differences be resolved?

b) What percentage of the U.S. population believes nuclear war is survivable?

-- is their belief based on facts?

-- is their belief based on feelings?
-- would their opinion be changed by the basic facts, if it is not now based on fact?

c) Does the U.S. public know the basic facts about nuclear radiation?

-- do they have basic knowledge of alpha, beta, and gamma radiation?
-- do they understand the concept of nuclear decay?
-- do they understand the basic defense against radiation of using mass or distance as a shield?
-- would a basic understanding of these principles influence public opinion about fallout shelters?

d) Does the level of public knowledge or ignorance of radioactive fallout effect public opinion about a national fallout shelter system?

-- can the level of public knowledge be raised in a non-threatening way?
-- is there a need for the public to understand these principles?

e) Will the international trend away from a strong bipolar world with the emergence of third-world power increase or decrease the need for fallout shelter protection?

f) Is the cost of implementing a national fallout shelter program the primary political objection, or is there a stronger objection?

g) Is the concept of fallout shelters obsolete?

-- Has the need for fallout shelter technology been overcome by world events?

h) Would home fallout shelters be effective against possible terrorist activities?

Appendix A: Fallout Shelter Plans

GENERAL INFORMATION

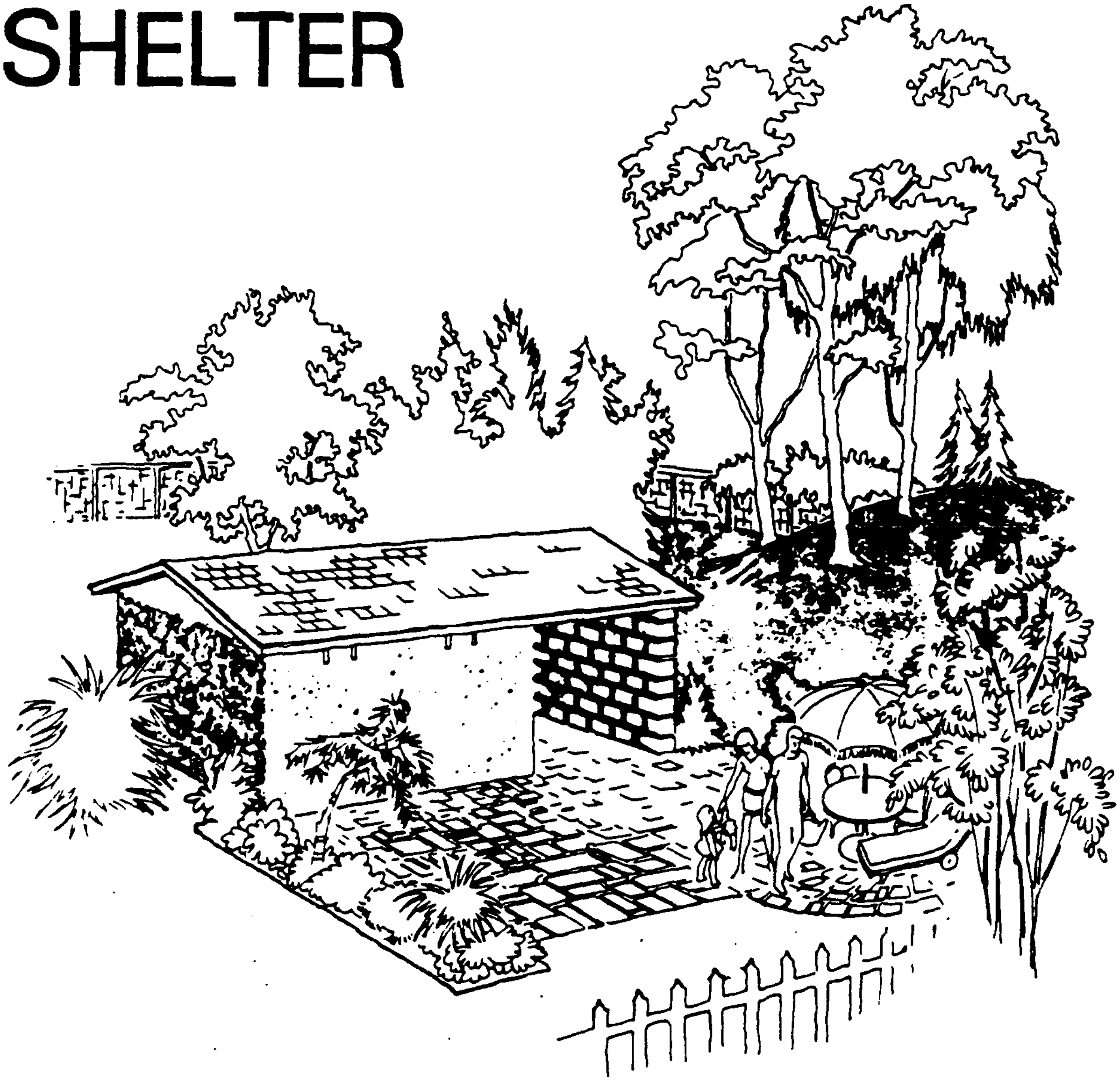
There is a wide range and variety of shelters available for home use. This sample of ten is given to provided a general idea some home shelter types. The FEMA documents are the cover sheets of actual booklets available through FEMA. Inside each FEMA booklet is the list of required materials and building plans. The FEMA designs are available from any local FEMA office, or from the National Emergency Publications Library, Washington D.C. Other designs are available from local, regional, and national contractors or distributors. I am not recommending any particular type, but offer these as an example of what is available.

For more information on home fallout shelters, contact your local FEMA office or write to one of their ten regional offices. The address and phone number is usually listed in the white pages of most phone books. Additionally, the research of C.V. Chester and G.P. Zimmerman titled, "Civil Defense Shelters - A State-of-the-Art Assessment - 1986," provides several good examples and a bibliography of over 1000 documents.

The next ten pages provide an example of ten different home shelter ideas.

H-12-2 / November 1983
(Supersedes H-12-2 dated June 1980)

ABOVEGROUND HOME FALLOUT SHELTER

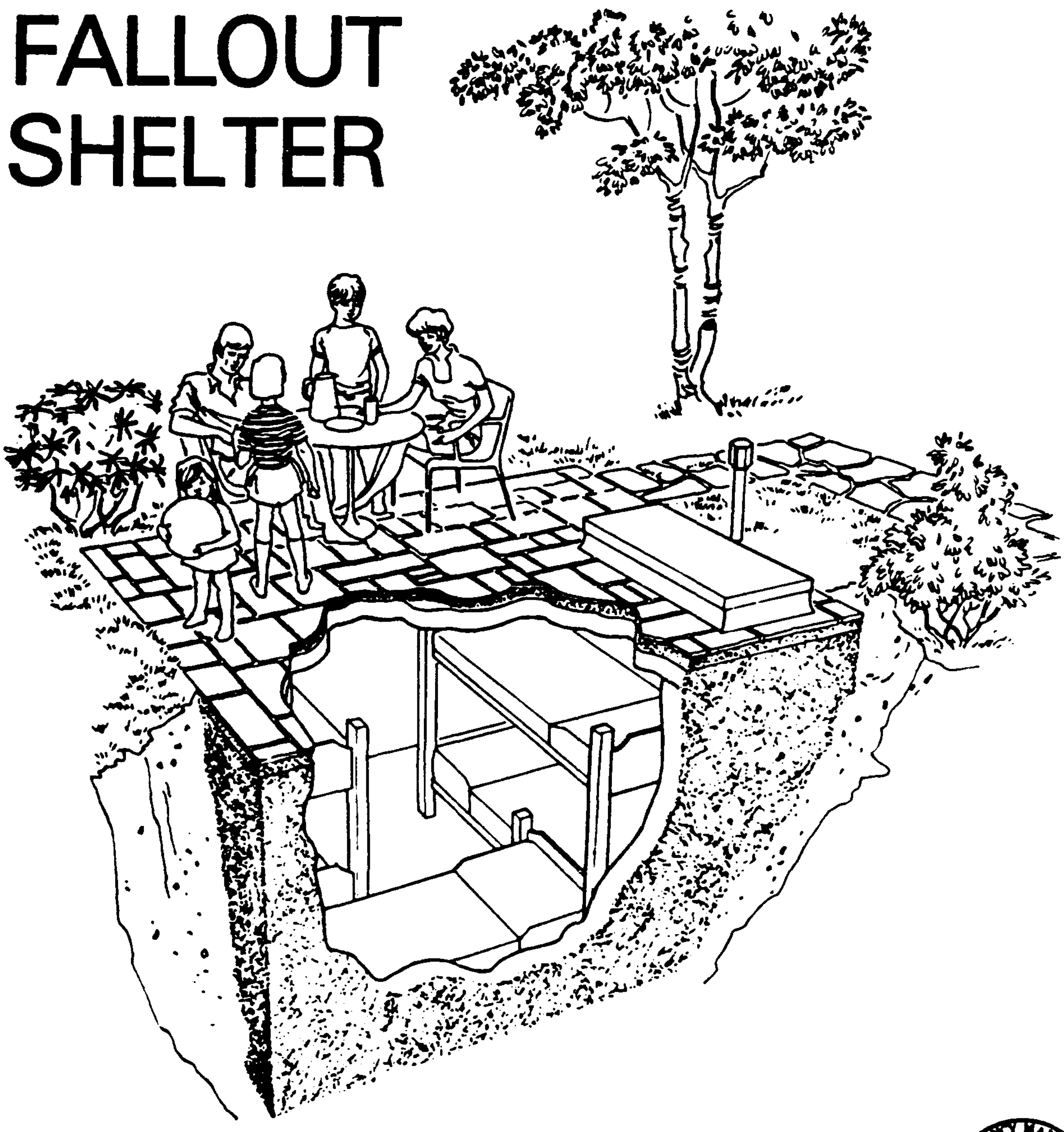


Federal Emergency Management Agency

(13:cover)

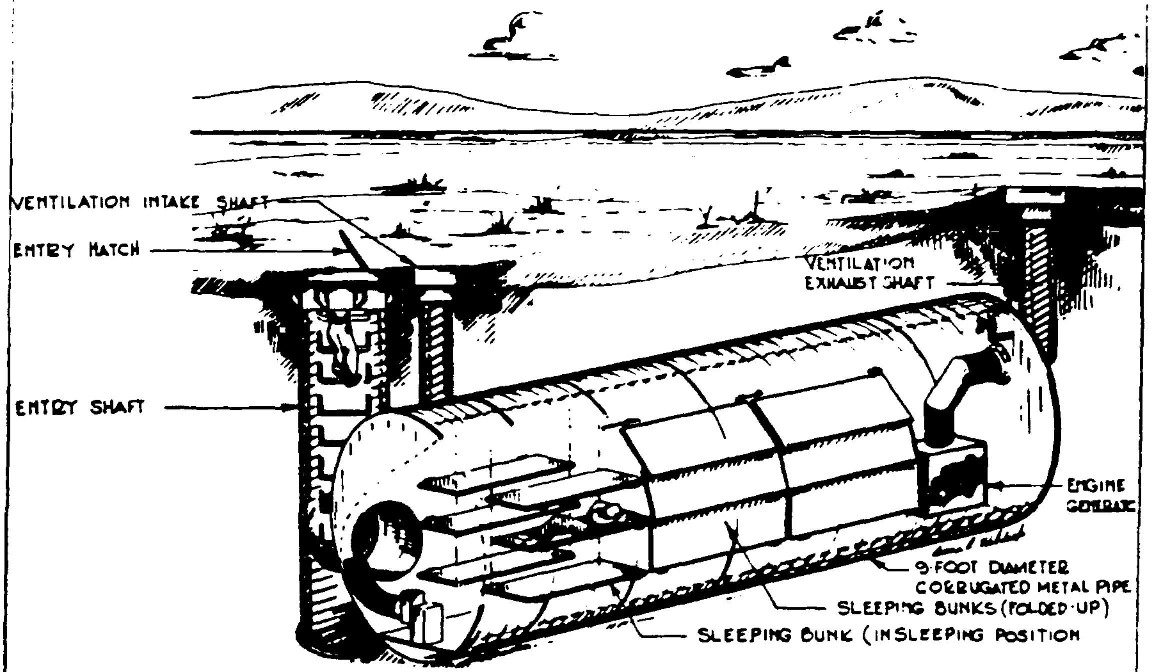
H-12-1 / November 1983
(Supersedes H-12-1 dated June 1980)

BELOWGROUND HOME FALLOUT SHELTER



Federal Emergency Management Agency

(15:cover)



Corrugated metal blast shelter (5:176)

A

H-12-A
April, 1980

Protection is provided
in a basement corner
by bricks
or concrete blocks
between the overhead joists.
A beam
and jack column
support the extra weight.

HOME FALLOUT SHELTER
modified ceiling shelter–basement location plan a

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(19:cover)

B

H-12-B
May 1980

Protection is provided
in a basement corner
by bricks
or concrete blocks
between the overhead joists.
Additional 2" x 12" joists
support
the extra weight.

HOME FALLOUT SHELTER
modified ceiling shelter–basement location plan b

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(20:cover)

C

H-12-C
May 1980

A compact shelter
is provided
in a basement corner
by the use of
common lumber
and concrete blocks
with mortar joints
for permanent construction.

HOME FALLOUT SHELTER
concrete block shelter—
basement location plan c

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(17:cover)

D

H-12-D
April 1980

A snack bar
built of brick
or concrete block
can be converted
into shelter.
The hinged canopy
can be tilted-down
for filling with brick
or concrete block.

HOME FALLOUT SHELTER
snack bar–
basement location plan d

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(21:cover)

E

H-12-E
April 1980

A storage unit is hinged
to the wall
in a basement corner.
It is tilted-up to rest on
stacked brick
or concrete block
and filled
for overhead protection.

HOME FALLOUT SHELTER
tilt-up storage unit shelter–basement location plan e

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(22:cover)

F

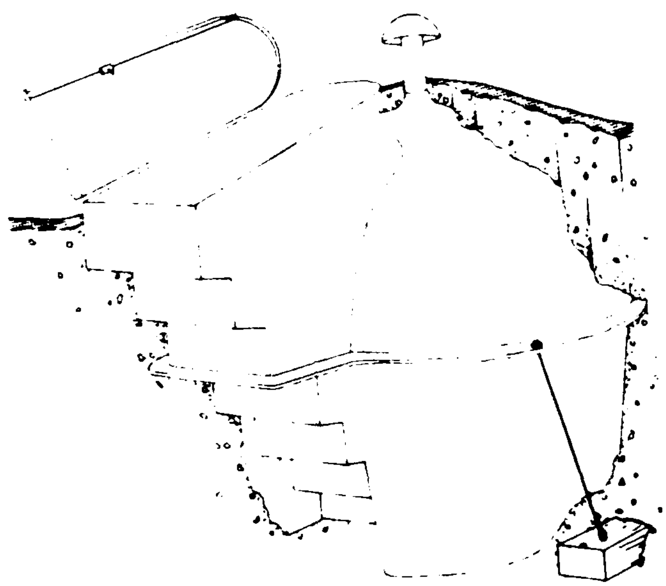
H-12-F
April 1980

Pre-built wood components
stored
in the basement
may be
assembled
and filled
with bricks
or concrete blocks
for emergency protection.

HOME FALLOUT SHELTER
lean-to shelter–
basement location plan f

FEDERAL EMERGENCY
MANAGEMENT AGENCY

(18:cover)



Additional Information Available from:

THE HOMESTEAD COMPANY
Box 86
Deerfield, MO 64741
phone: (417) 966-7322

Homestead Company Storm Cellar Shelter (5:161)

Appendix B: Glossary

ABSORBED DOSE. The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest. The unit absorbed is the RAD.

AFTERWINDS. Wind currents set up in the vicinity of a nuclear explosion directed toward the burst center, resulting from the updraft accompanying the rise of the fireball.

AIR BURST. The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface when the luminosity is a maximum (in the second pulse).

ALPHA PARTICLE. A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus, having a mass of four units and an electric charge of two positive units. See also radioactivity.

ALPHA RADIATION. Rays of alpha particles.

ALPHA RAYS. An alpha particle moving at high speed, or a stream of such particles.

ATMOSPHERE. A unit of pressure equal to 14.69 psi.

ATOM. The smallest (or ultimate) particle of an element that still retains the characteristics of that element. Every atom consists of a positive charged central nucleus, which carries all the mass of the atom, surrounded by a number of negatively charged electrons, so the whole system is electrically neutral.

ATOMIC BOMB. A term sometimes applied to a nuclear weapon using fission energy only.

BARRIER SHIELDING. Shielding gained by placing a physical barrier between a given point and a radiation source.

BETA BURN. Damage to the skin caused by prolonged contact with particles that emit beta radiation.

BETA PARTICLE. A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most, if not all, of the direct fission products emit negative beta particles. Physically, the beta particle is identical to an electron moving at high velocity.

BETA RAY. A beta particle moving at high speed, or a stream of such particles.

BETA RADIATION. Rays of beta particles.

BLAST WAVE. A pulse of air in which the pressure increases sharply at the front, accompanied by winds, propagated continuously from an explosion.

CGY. Usually written cGy, it stands for 'midline absorbed photon energy'. A unit computed by the Los Alamos National Laboratory in their model for human lethality. 1 cGy = 1 rad.

CLEAN WEAPON. One where measures are taken to reduce the amount of residual radioactivity relative to normal weapons of the same energy yield.

CONTAMINATION (RADIOACTIVE). Radioa ive material deposited on the surface of structures, ..eas, objects, or persons following a nuclear explosion. This material usually consists of fallout where fission products and other weapon debris have become incorporated with particles of dirt, etc.

CUMULATIVE DOSE. The total dose resulting from continued or repeated exposures to radiation.

COUNTERMEASURES. Protective actions to reduce the effects of nuclear explosions, including fallout upon the population.

DECAY (RADIOACTIVE DECAY). The decrease in activity of any radioactive material with the passage of time, due to spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation.

DECONTAMINATION (RADIOACTIVE). The removal or covering of radioactive contamination from structures, areas, objectives, or persons, to reduce the radiation hazard.

DIRTY WEAPON. One which produces a larger amount of radioactive residues than a normal weapon of the same yield.

DOSE. A total or accumulated quantity of ionizing (nuclear) radiation. The term dose can be used in the sense of:

a) The Exposure Dose, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air;

b) The Absorbed Dose, given in reps or rads, which is the energy absorbed from the radiation per gram of specific body tissue; or
c) The Biological Dose, in rems, which is a measure of the biological effectiveness of the radiation exposure.

DOSE RATE. The amount of ionizing radiation to which a person would be exposed or receive per unit of time. It is usually expressed in roentgens, rems, or rads per hour, or in multiples or submultiples of these units.

DOSE PENALTY TABLE. A table of radiation exposure constraints that provides a simple guide for use by decision-makers.

DYNAMIC PRESSURE. The air pressure which results from the mass air flow (or wind) behind the shock front of a blast wave.

ELECTROMAGNETIC PULSE (EMP). Energy radiated by a nuclear detonation in the medium-to-low frequency range that may affect or damage electrical or electronic components and equipment.

ELECTROMAGNETIC RADIATION (EMR). A traveling wave motion resulting from oscillating magnetic and electrical fields. They range from X-ray (and gamma rays) through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength. All EAR travels in a vacuum with the velocity of light.

ELECTRON. A particle of very small mass, carrying a unit of negative or positive charge. Negative electrons, surrounding the nucleus, are present in all atoms; their number is equal to the number of positive charges (or protons) in the particular nucleus.

ERG. A unit of energy or work. An erg is the energy required for an electron to ionize about 20 billion molecules of air.

EXPOSURE. A quantitative measure of gamma or X-ray radiation at a given place, based on its ability to produce ionization in air, measured in units of roentgens.

FALLOUT. The process or phenomenon of the fallback to the earth's surface of particles contaminated with radioactive material from a radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself.

FALLOUT (continued)
There are two general types of fallout:

a) Early fallout in arbitrarily defined as those particles which reach the earth within 24 hours.

b) Delayed fallout consists of smaller particles which ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the earth.

FALLOUT SHELTER. An enclosed area or place which can provide refuge and protection against fallout radiation by absorbing some or most of the radiation directed toward the shelter.

FEMA. Federal Emergency Management Agency.

FIREBALL. The luminous sphere of hot gases which form a few millionths of a second after a nuclear explosion. It is caused by surrounding medium absorbing the thermal X-rays emitted by the extremely hot (several tens of millions of degrees) weapon residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves (radiation front).

FIRE STORM. Stationary mass fire, generally in built-up urban areas, generating strong inrushing winds from all sides: the winds keep the fire from spreading while adding fresh oxygen to increase their intensity.

FISSION. The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium 235 and plutonium 239.

FLASH BURN. A burn caused by excessive exposure (of bare skin) to thermal radiation.

FREE AIR OVERPRESSURE. The unreflected pressure, in excess of ambient atmospheric pressure, created in the air by the blast wave from an explosion.

FUSION. The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely deuterium and trite, combine to form the nucleus of a heavier element, with the release of substantial amounts of energy.

GAMMA RAYS (OR RADIATIONS). Electromagnetic radiations of high energy originating in atomic nuclei and accompanying many nuclear reactions, e.g., fission, radioactivity, and neutron capture. Physically, gamma rays are identical to

X-rays of high energy, the essential difference being X-rays don't originate from atomic nuclei.

GEOMETRY SHIELDING. Shielding gained by distance from a source of radiation.

GRAY. A metric unit for measuring doses of ionizing radiation. A rad, which is more common in U.S. terminology, is one one-hundredth of a gray.

GROUND BURST. A nuclear detonation at the surface of the earth, or at such a height above the earth that the fire-ball makes contact with the surface. See also surface burst.

GROUND ZERO. The point on the surface of land or water vertically below or above the center of a nuclear weapon burst.

HALF-LIFE. The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactivity decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition. The effective half-life of a given isotope is the time needed for the quantity in the body to decrease to half, due to both radioactive decay and biological elimination.

HALF-VALUE THICKNESS. The thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material - it is roughly inversely proportional to its density - and also on the energy of the gamma rays.

HIGH-ALTITUDE BURST. This is defined, somewhat arbitrarily, as a detonation at an altitude over 100,00 feet. Above this level, the distribution of the energy of the explosion between blast and thermal radiation changes appreciably with increasing altitude due to changes in the fireball phenomena.

HIGH-FALLOUT RISK AREA. An area with the potential for receiving exceptionally high levels of fallout radiation, but not designated a high-risk area. The principal criterion is a computer analyzed prediction of a 6,000R or greater dose of fallout radiation within one week. It's based on location and wind pasterns.

HIGH-RISK AREA. An area where national policy directs preparation to protect the population from the direct effects of nuclear explosions as well as fallout. The principal criterion is blast overpressures of 2 psi or greater and/or fires following a large-scale nuclear attack.

HOST AREA. An area analyzed as subject to less serious effects of a large-scale nuclear attack. It is considered suitable for receiving evacuees from higher risk areas and providing life sustaining protection and support.

HYDROGEN BOMB (OR WEAPON). A term sometimes applied to nuclear weapons in which part of the explosive energy is obtained from nuclear fusion reactions.

INITIAL NUCLEAR RADIATION. The nuclear radiation, essentially neutrons and gamma rays, emitted from the fireball and the cloud column during the first minute after a nuclear explosion. One minute is the time require for part of the radiation source to attain such a height that only insignificant amounts reach the earth's surface.

IONIZATION. The separation of a normally electrically neutral atom into electrically charged components. It refers especially to the removal of a negatively charged electron from an atom, leaving a positively charged ion. The separated electron and ion are referred to as an electron pair.

IONIZING RADIATION. Electromagnetic radiation (gamma rays or X-rays) or particle radiation (alpha particles, beta particles, or neutrons) capable of producing ions as it passes through matter.

ISOTOPES. Forms of the same element having identical chemical properties but differing in their atomic masses and their nuclear properties. For example, hydrogen has three isotopes with masses of 1 (hydrogen), 2 (deuterium), and 3 (tritium) units respectively. Hydrogen and deuterium are stable (nonradioactive), but tritium is a radioactive isotope.

KILOTON ENERGY (KT). The energy of a nuclear explosion equal to that produced by exploding 1,000 tons of TNT.

LETHAL RADIATION DOSE. The total-body radiation exposure required to cause death in 100 percent of a large group of people within a specified time period.

LD-50. The dose that causes lethal radiation sickness in 50 percent of an exposed population within about 60 days.

MACH STEM. The shock front formed by the fusion of the incident and reflected shock fronts from an explosion. The term is generally used with reference to a blast wave, propagated in the air, reflected at the surface of the earth. The Mach Stem is nearly perpendicular to the reflecting surface and presents a slightly convex front.

MASS. A measure of the quantity of matter. The material equivalent of energy. Mass and energy are different forms of the same thing.

MEDIAN LETHAL DOSE. The amount of ionizing radiation exposure over the whole body which, it is expected, would be fatal to 50 percent of a large group of living creatures or organisms. It is commonly accepted that about 450 roentgens, received over the whole body in the course of a few days or less, is the median lethal dose for humans.

MEGATON ENERGY (MT). The energy of a nuclear explosion which is equivalent to the energy of exploding 1,000,000 tons of TNT.

NEUTRON. A neutral particle, with no electrical charge, present in all atomic nuclei except ordinary hydrogen. Neutrons are required to initiate the fission process and large numbers are produced by both fission and fusion reactions in nuclear explosions.

NUCLEAR ATTACK PREPAREDNESS. Actions taken to protect citizens in the event of a nuclear attack upon the U.S. The purpose is to enhance the survivability and recovery of our population and leadership, reducing our vulnerability to nuclear war or attack.

NUCLEAR RADIATION. Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. All nuclear radiations, alpha and beta particles, neutrons and gamma rays, are ionizing radiations.

NUCLEAR WEAPON (OR BOMB). A general name given to any weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission, fusion, or both.

NUDET. Report of a nuclear detonation.

OUTSIDE/INSIDE RATIO (OI). The measured ratio of the fallout gamma radiation exposure rate at some point outside a shelter to the exposure rate at some point inside the shelter.

OVERPRESSURE. The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock wave from an explosion.

PEAK OVERPRESSURE. The maximum overpressure value at the blast front.

PHOTON. A unit or particle of electromagnetic energy with no mass or electric charge. Visible light is made up of

low-energy photons, whereas, gamma rays are high-energy photons.

PROTECTION FACTOR (PF). A theoretical value that defines the ratio of the exposure rate from fallout gamma radiation to be expected in a protected location compared to the exposure rate expected in a completely unprotected location on an infinitely smooth plane.

PROTON. A particle of mass carrying a unit positive charge. All atomic nuclei contain protons.

PSI. Usually written in smaller case, it is the abbreviation for 'pounds per square inch'.

RAD. A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear radiation per gram of the absorbing material or tissue.

RADIATION INJURY. The harmful effects caused by ionizing radiation.

RADIOACTIVE CLOUD. An all-inclusive term for the mixture of hot gases, smoke, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon.

RADIOACTIVITY. The spontaneous disintegration of unstable nuclei with the resulting emission of nuclear radiation.

RAINOUT. The process of removing particles of fallout from the air either by the formation of water droplets around the particles which then fall as rain, or by rain falling through the fallout cloud and "washing" the particles down to earth. Rainout does not affect fallout particles that are higher than 10 km (33,000 ft).

REM. A unit of biological dose of radiation; the name is derived from the initial letters of the term "Roentgen equivalent man (or mammal)."

REP. A unit of absorbed dose of radiation now being replaced by rad; the name is derived from the initial letters of the term, "Roentgen equivalent physical." It was intended to express the amount of energy absorbed per gram of tissue as a result of exposure to 1 Roentgen of gamma radiation.

RESIDUAL NUCLEAR RADIATION. Nuclear radiation, chiefly beta particles and gamma rays, which persists for some time following a nuclear explosion.

ROENTGEN (R). A unit of exposure to X-ray or gamma radiation. It is defined precisely as the quantity of gamma radiation such that the associated corpuscular emissions per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit quantity of electricity of either sign. From the accepted value (34 electron volts) for the energy lost by an electron in producing a positive-negative ion pair in air, it is estimated that 1 Roentgen of gamma radiation would result in the absorption of about 87 ergs of energy per gram of air.

SHELTER. A habitable structure or space stocked with essential provisions and used to protect its occupants from fallout, fire, blast overpressure, or rubble. See also fallout shelter.

SHIELDING. Any material or obstruction which absorbs radiation and thus tends to protect personnel or materials from the effects of a nuclear explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for nuclear radiation shielding.

SHOCK WAVE. A continuously propagated pressure pulse (or wave) in the surrounding medium, which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion.

SURFACE BURST. The explosion of a nuclear weapon at the surface of the land or water or at a height above the surface less than the radius of the fireball at maximum luminosity.

THERMAL ENERGY. The energy emitted from the fireball as thermal radiation. The total amount of thermal energy received per unit at a specified distance from a nuclear explosion is generally express in calories per square centimeter.

THERMONUCLEAR. An adjective referring to the process in which very high temperatures are used to bring about the fusion of light nuclei, with the accompanying liberation of energy. The high temperatures required are obtained by means of a fission explosion.

THERMAL RADIATION. Electromagnetic radiation emitted from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiations.

UNDERGROUND BURST. The explosion of a nuclear weapon with its center more than 5W(to the 0.3 power) feet, where W is

the explosion yield in kilotons, beneath the surface of the ground.

X-RAY. A photon of high energy, or a stream of such photons, resulting from a process other than nuclear transformations.

YIELD (OR ENERGY YIELD). The total effective energy released in a nuclear explosion. It is usually express in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifest as nuclear radiation, thermal radiation, and shock (blast).

Appendix C: Additional References

The following references are recommended by Chester and Zimmerman in their study, Civil Defense Shelters A State-of-the-Art Assessment - 1986 (5). I grouped them alphabetically according to the nuclear weapon effect of interest.

For additional information on blast effect, Chester and Zimmerman recommend the following references:

Avise, H.J. Development of a Shelter Blast and Fire Vulnerability Data System. Bethesda MD: System Science, Inc., 1971.

Brode, H.L. A Review of Nuclear Explosion Phenomena Pertinent to Protective Construction. Santa Monica CA: Rand Corporation, 1964.

Brotherson, D.E. et al. Limited Blast Resistance in Houses. Urbana-Champaign IL: University of Illinois, 1968.

Crowley, J.W. et al. Development of Analytical Relationships and Criteria for Blast and Fire Vulnerability of Fallout Shelter Occupants. Bethesda MD: Systems Science, Inc., 1968.

Federal Emergency Management Agency. FEMA, Attack Environment Manual (Civil Preparedness Guide; Chapter 1: Introduction to Nuclear Emergency Operations). Washington: U.S. Government Printing Office, 1982.

Hickman, R.G. and C.A. Meier. Proceedings of the Asilomar Conference on Fire and Blast Effects of Nuclear Weapons. Livermore CA: Lawrence Livermore Laboratory, 1983.

Hobbs, N.P. and K.R. Wetmore. PIVUL: A Computer Code for Rapid Assessment of the Vulnerability of Simple Structures to Blast. Burlington MA: Kaman-AviDyne, 1980.

Longinow, A. et al. Civil Defense Shelter Options for Fallout and Blast Protection. Chicago: Illinois Institute of Technology, 1982.

Longinow, A. et al. Casualties Produced by Impact and Related Topics of People Survivability in a Direct Effects Environment. Chicago: IIT Research Institute, 1974.

Longinow, A. et al. Combined Effects of Blast and Fire on Personnel Survivability. Chicago: IIT Research Institute, 1968.

Longinow, A. Probability of People Survival in a Nuclear Weapon Blast Environment. Chicago: IIT Research Institute, 1980.

Pickering, E.E. and J.L. Bockholt. Probabilistic Air Blast Failure Criteria for Urban Structures. Menlo Park CA: Stanford Research Institute, 1971.

Pinkston, J.M., Jr. Attenuation of Airblast in Open Entranceways of Blast-Protective Structures. Vicksburg MS: U.S. Army Engineer Waterway Experiment Station, 1964.

Richmond, et al. Air-Blast Studies with Eight Species of Mammals. Albuquerque NM: Lovelace Foundation for Medical Education and Research, 1966.

Richmond, D.R. and E.R. Fletcher. The Effects of Air-Blast on Sheep in Two-Man Foxholes. Albuquerque NM: Lovelace Foundation for Medical Education and Research, 1971.

Schmidt, L.A. Sensitivity Analysis of Urban Blast Fatality Calculations. Arlington VA: Institute for Defense Analysis, 1971.

Lin, N. et al. The Diffusion of the Slanting Techniques: A Study of the Direct Mail Shelter Development System. Albany NY: State University of New York, 1972.

Wiehle, C.K. Evaluation of Existing Structures. Menlo Park CA: Stanford Research Institute, 1974.

For more information on ground motion and shock, Chester and Zimmerman recommend these references:

Ammann and Whitney. *An Introduction to Protective Design for Nuclear Weapons Effects.* New York: Office of Civil Defense, 1965.

Collins, J.D. et al. *Uncertainties in the Ground Shock Estimate Process.* Redondo Beach CA: J.H. Wiggins, Co., 1965.

Daniels, R.D. *An Analysis of Uncertainties in the Ground Shock Estimation Process.* Redondo Beach CA: J.H. Wiggins, Co., 1979.

Davis, L.L. *A Summary of Ground Motion Prediction Procedures and Equations.* Alexandria VA: Roland F. Beers, Inc., 1965.

French, R.L. and L. Olmeno. *Ground Roughness Calculations for Fallout Gamma Rays.* Fort Worth TX: Radiation Research Associates, Inc., 1966.

French, R.L. et al. *Ground Roughness Effects on Fallout Shielding.* Fort Worth TX: Radiation Research Associates, Inc., 1968.

Hadala, F.P. *Effect of Constitutive Properties of Earth Media on Outrunning Ground Shock from Large Explosions.* Vicksburg MS: U.S. Army Engineer Waterway Experiment Station, 1973.

Jackson, J.G., Jr. *Site Characterization for Probabilistic Ground Shock Predictions.* Vicksburg MS: U.S. Army Engineer Waterway Experiment Station, 1982.

Lipner, N. et al. *Ground Motion Environments for Generic Site Conditions.* Redondo Beach CA: TRW Systems Group, 1975.

Merritt, J.L. and N.M. Newmark. *Design of Underground Structures to Resist Nuclear Blast.* Urbana IL: University of Illinois, 1958.

Morrison, T. *Design Procter for Shock Isolation Systems of Underground Protective Structures - Volume I: Structure Interior Motions Due to Air Blast Induced Ground Shock.* Niles IL: General American Transportation Corp., 1964.

Murphy, H.L. *Ground Motion Predictions for Nuclear Attack Area Studies.* Menlo Park CA: Stanford Research Institute, 1967.

Murphy, J.R. et al. Analysis of Low Frequency Ground Motions Induced by Near-Surface and Atmospheric Explosions. La Jolla CA: S-Cube, 1982.

Perret, W.R. Ground Motion Studies at High Incident Overpressure. Albuquerque NM: Sandia Corp, 1960.

Sevin, E. et al. Ground Shock Isolation of Buried Structures. Kirkland AFB NM: U.S. Air Force Special Weapons Center, 1961.

For more information on fires as they relate to shelters and on the interaction of NUDETS and fires, Chester and Zimmerman suggest these references:

Avise, H.J. Development of a Shelter Blast and Fire Vulnerability Data System. Bethesda MD: System Science, Inc., 1971.

Broido, A. and A.W. McMasters. Effects of Mass Fires on Personnel in Shelters. Berkeley CA: USDA, 1960.

Crowley, J.W. et al. Development of Analytical Relationships and Criteria for Blast and Fire Vulnerability of Fallout Shelter Occupants. Bethesda MD: Systems Science, Inc., 1968.

Goodale, T. An Attempt to Explore the Effects of High Blast Overpressure on the Persistence of Smoldering Combustion in Debris. San Mateo CA: URS Research Co., 1971.

Hedge, J.C. and T.E. Waterman. Fire Test Ratings for Shelter Components. Chicago: IIT Research Institute, 1969.

Lee, W. et al. Design of Tests for the Effects of Mass Fires on Shelter Occupants. Palo Alto CA: Hazelton-Nuclear Science Corp., 1966.

Longinow, A. et al. Assessment of Combined Effects of Blast and Fire on Personnel Survivability. Chicago: IIT Research Institute, 1982.

Smith, J.B. et al. Fire Hazard to Fallout Shelter Occupants A Classification Guide. Norwood MA: Factory Mutual Research Corp., 1964.

Takata, A.N. and T.E. Waterman. Fire Laboratory Test - Phase II: Interaction of Fire and Simulated Blast Debris. Chicago: IIT Research Institute, 1972.

Waterman, T.E. Shelter Habitability in Existing Building Under Fire Exposure. Chicago: IIT Research Institute, 1966.

For additional information on initial nuclear radiation, Chester and Zimmerman suggest the following references:

Abbott, L.S. Shielding Against Initial Radiations from Nuclear Explosions. Oak Ridge TN: Oak Ridge National Laboratory, 1973.

Albert, T.E. et al. Sensitivity of INR Shielding Analyses to Source and Structural Variations. La Jolla CA: Science Applications, Inc., 1977.

Auxier, J. A. et al. Nuclear Weapon Free-Field Environment Recommended for Initial Radiation Shielding Calculations. Oak Ridge TN: Oak Ridge National Laboratory, 1972.

Federal Emergency Management Agency. FEMA Attack Environment Manual (Civil Preparedness Guide; Chapter 5: What the Planner Needs to Know About Initial Nuclear Radiation). Washington: U.S. Government Printing Office, 1980.

Ferlic, K.P. Fallout: Its Characteristics and Management. Bethesda MD: Armed Forces Radiobiology Institute, 1971.

French, R.L. and L.G. Mooney. Initial Radiation Exposure from Nuclear Weapons. Fort Worth TX: Radiation Research Associates, Inc., 1972.

The following are references on a variety of topics related to shelters, and the effects of nuclear weapons:

Committee for the Compilation of Materials on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki. Hiroshima and Nagasaki - The Physical, Medical, and Social Effects of the Atomic Bombings (translated from Japanese by E. Ishikawa and D.L. Swain). New York: Basic Books, Inc., 1981.

Coulter, G.A. Blast Loading of Closures for Use on Shelters. Aberdeen Proving Ground MD: U.S. Ballistic Research Laboratory, 1983.

Earp, X.F. Deaths from Fire in Large Scale Air Attack - With Special Reference to the Hamburg Fire Storm. Great Britain: Scientific Advisor's Branch, Whitehall, 1953.

Glasstone, S. and P.J. Dolan. The Effects of Nuclear Weapons - 1977 (Third Edition). Washington: U.S. Government Printing Office, 1977.

Harvey, T.F. and F.J.D. Serduke. Fallout Model for System Studies. Livermore CA: Lawrence Livermore Laboratory, 1979.

Kucher, V. and J. Harrison. Air Shock Filling of a Model Room. Aberdeen Proving Ground MD: U.S. Army Ballistic Research Laboratory, 1977.

Lacayo, H., Jr. and M.A. Sullivan. Significance of Fallout Ingress into Shelters. San Francisco: U.S. Naval Radiological Defense Laboratory, 1967.

Mather, R.L. Ground Roughness Effects in Fallout Radiation Fields. San Francisco: U.S. Naval Radiological Defense Laboratory, 1968.

Miller, C.F. Firefighting Operations in Hamburg, Germany During World War II: Excerpts from the Hamburg Fire Department Documents on the Air Attacks During World War II, Appendixes 3, 4, and 5 and Photographs. Burlingame CA: United Research Services, Inc. 1972.

Read, P.A. Models of Ground Roughness in a Fallout Field. San Francisco: U.S. Naval Radiological Defense Laboratory, 1967.

Rempel, J.R. Ground Shock and the Survival of the Contents of Personnel Shelters (Part I--Resistance of Human and Inanimate Contents of Hardened Shelters to Nuclear-Induced Ground Motion, Menlo Park CA: Stanford Research Institute, 1967.

Shumway, B.W. and A.L. Frank. Angular Radiation Characteristics of Rough Surfaces Contaminated with Fallout Simulant. San Francisco: U.S. Naval Radiological Defense Laboratory, 1968.

Stubbs, I.R. Blast and Impact Exposures of Existing Structural Fire Protection Schemes. Van Nuys CA: T.Y. Lin and Associates, 1965.

Ullrich, G.W. Proceedings of the Nuclear Blast and Shock Symposium. Santa Barbara CA: General Electric - TEMPO, 1978.

Bibliography

1. Ashby, Timothy. "Civil Defense and the 'Winnable' Nuclear War - Contrasting Approaches of the United States and the Soviet Union," RUSI Journal of the Royal United Services Institute for Defense Studies, 128: 47-52 (March 1983).

2. Beres, Louis Rene'. "Surviving Nuclear War: U.S. Plans for Crisis Relocation," Armed Forces and Society, 12: 75-94 (Fall 1985).

3. Bush, George H.W., President of the United States. Comments broadcast on the Presidential Press Conference, CBS, 11 July 1990.

4. Cary, Peter and Bruce B. Auster. "Best and Worst Weapons," U.S. News and World Report, 107: 23-24 (July 10, 1989).

5. Chester, Charles V. and Gregory P. Zimmerman. Civil Defense Shelters: A State-Of-The-Art Assessment - 1986. Interagency Agreement EMW-84-E-1737. Oak Ridge TN: Oak Ridge National Laboratory, December 1986.

6. Church, George J. "How Much is Too Much?", Time, 135: 16-21 (February 12, 1990).

7. Coleman, Fred. "People Want to Get Rid of Communism," Newsweek, 115: 29-30 (May 14, 1990).

8. Daugherty, William H. et al. "The Consequences of 'Limited' Nuclear Attacks on the United States," International Security, 10: 3-45 (Spring 1986).

9. Defense Civil Preparedness Agency. Radiological Defense Manual. CPG 2-6.2. Washington: DCPA DoD, June 1977.

10. Duffy, Bryan et al. "The Man Who Would Be King," U.S. News and World Report, 109: 20-25 (August 13, 1990).

11. Ehrlich, Robert and James Ring. "Fallout Sheltering: is it Feasible?", Health Physics, 52: 267-279 (March 1987).

12. Elmquist, Michael H. "Ready for Disaster? Civil Preparedness in NATO," NATO's Sixteen Nations, 34: 54-63 (April 1989).

13. Federal Emergency Management Agency. Aboveground Home Fallout Shelter H-12-2. Washington: FEMA, November 1987.

14. -----. American Civil Defense 1945-1984 - The Evolution of Programs and Policies. FEMA 107. Washington: FEMA, July 1986.

15. -----. Belowground Home Fallout Shelter. H-12-1. Washington: FEMA, November 1987.

16. -----. A Comparison of Soviet and U.S. Civil Defense Programs. FEMA 161. Washington: FEMA, July 1988.

17. -----. Home Fallout Shelter, Concrete Block Shelter - Basement Location Plan C. H-12-C. Washington: FEMA, May 1980.

18. -----. Home Fallout Shelter, Lean-to Shelter - Basement Location Plan F. H-12-F. Washington: FEMA, May 1980.

19. -----. Home Fallout Shelter, Modified Ceiling Shelter - Basement Location Plan A. H-12-A. Washington: FEMA, May 1980.

20. -----. Home Fallout Shelter, Modified Ceiling Shelter - Basement Location Plan B. H-12-B. Washington: FEMA, May 1980.

21. -----. Home Fallout Shelter, Snack Bar - Basement Location Plan D. H-12-D. Washington: FEMA, May 1980.

22. -----. Home Fallout Shelter, Tilt-up Storage Unit Shelter - Basement Location Plan E. H-12-E. Washington: FEMA, May 1980.

23. -----. Instructions For Building A Home Shelter. H-12-4.1. Washington: FEMA, October 1987.

24. -----. Radiation Safety In Shelters. CPG 2-6.4. Washington: FEMA, 23 September 1983.

25. -----. Recovery From Nuclear Attack. FEMA 160. Washington: FEMA, October 1988.

26. -----. Soviet Civil Defense. FEMA 52. Washington: FEMA, September 1982.

27. House Committee on Armed Services. Hearings on Military Posture and H.R. 9637. HASC Paper No. 36, 88th Congress, 2d Session, 1964. Washington: Government Printing Office, 1964.

28. Jackson, James O. "Marching to Unity," Time, 135: 30-32 (February 12, 1990).

29. Lamperti, John. "What Harm Can it Do?," Bulletin of the Atomic Scientists, 39: 7S-10S (June-July 1983).

30. Leaning, Jennifer. "Star Wars Revives Civil Defense," Bulletin of the Atomic Scientists, 43: 42-46 (May 1987).

31. Marshall, Eliot. "Armageddon Revisited," Science, 236: 1421-1422 (June 12, 1987).

32. Miller, C.F. Firefighting Operations in Hamburg, Germany During World War II: Excerpts from the Hamburg Fire Department Documents on the Air Attacks During World War II, Appendixes 3, 4, and 5 and Photographs. Burlingame CA: United Research Services, Inc. 1972.

33. Office of the President of the United States. National Security Strategy of the United States. Washington: The White House, 1990.

34. Orient, Jane M. "Medical Preparedness and Nuclear War," Vital Speeches of the Day, 55: 186-190 (January 1989).

35. "Overtaking Arms Control," U.S. News and World Report, 108: 30 (June 11, 1990).

36. Peppers, Jerome G. A History of United States Military Logistics 1935-1985. Huntsville AL: Logistics Education Foundation Publishing, 1988.

37. Secretary of the Air Force. The Air Force and U.S. National Security. A White Paper. Washington: Government Printing Office, 1990.

38. Troxel, Captain John F. "Soviet Civil Defense and the American Response," Military Review, 63: 36-46 (January 1983).

39. U.S. Congress Joint Committee on Defense Production. Deterrence and Survival in the Nuclear Age. Reprint of a 1957 report by the Security Resources Panel of the Science Advisory Committee. 94th Congress, 2d Session, 1976. Washington: Government Printing Office, 1976.

40. U.S. General Accounting Office. Activities and Status of Civil Defense in the United States. Report to Congress. Washington: GAO, Comptroller General, 1971.

41. Von Hippel, Frank N. et al. "Civilian Casualties from Counterforce Attacks," Scientific American, 259: 36-42 (September 1988).

42. "The Worst Weapons," U.S. News and World Report, 107: 25-26 (July 10, 1989).

Vita

Major Val J. Evans [redacted] graduated from Bonneville High School in 1968, and Weber State College in 1975, both in Ogden, with a B.S. degree in Biology and a Secondary Education Certificate. He taught High School Biology for three years then entered the U.S. Air Force through Officer Training School where he was commissioned in 1979. Major Evans was then assigned to the 510th Strategic Missile Squadron, Whiteman AFB, MO, where he served as Deputy Missile Combat Crew Commander (DMCCC), Instructor DMCCC, and Missile Combat Crew Commander. While there, he earned a M.S. degree in Industrial Safety in 1983 from Central Missouri State University. After attending Squadron Officer School at Maxwell AFB, AL, he was assigned to the 4315th Combat Crew Training Squadron, Vandenberg AFB, CA in 1983, as a Combat Crew and Training Science Instructor. In November 1986, he was assigned to the 90th Strategic Missile Wing at F.E. Warren AFB, WY as Chief, Instructional Systems Development Division and later as Assistant Operations Officer with the 321st Strategic Missile Squadron. Major Evans entered the School of Systems and Logistics, Air Force Institute of Technology, in June 1989, and promoted to major in September 1990.

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This study investigated the question "Why are fallout shelters not a part of U.S. national defense strategy and policy?" Initial research determined that the U.S. has the technology to design and build shelters, they are effective protection from radioactive fallout, and nuclear aggression against the U.S. remains a potential national threat. The research examined the physical threats posed by nuclear weapons, followed by a brief description of fallout shelters and their ability to shield against fallout radiation in terms of the ratio of time in shelter to amount of exposure. Several opposing arguments from opponents and proponents of a national fallout shelter program were categorized and expressed within U.S. National Security Strategy, military, economic, and political terms. The principal argument against a national fallout shelter program, including home fallout shelters, is the momentum of over 30 years of successful deterrence. On the other hand, the relatively simple technology, the affordability, and the potential for saving millions of lives in low-risk areas that would otherwise be lost should deterrence fail, argue strongly in favor of a national home fallout shelter system. Keywords:

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